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PROCEEDINGS  
AND  
TRANSACTIONS  
OF THE  
LIVERPOOL BIOLOGICAL SOCIETY.

T.P.  
VOL. XXII.

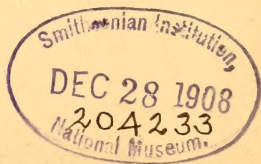
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SESSION 1907-1908.

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LIVERPOOL:  
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—  
1908.







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PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.





## OFFICE-BEARERS AND COUNCIL.

---

### Ex-Presidents :

- 1886—87 PROF. W. MITCHELL BANKS, M.D., F.R.C.S.  
1887—88 J. J. DRYSDALE, M.D.  
1888—89 PROF. W. A. HERDMAN, D.Sc., F.R.S.E.  
1889—90 PROF. W. A. HERDMAN, D.Sc., F.R.S.E.  
1890—91 T. J. MOORE, C.M.Z.S.  
1891—92 T. J. MOORE, C.M.Z.S.  
1892—93 ALFRED O. WALKER, J.P., F.L.S.  
1893—94 JOHN NEWTON, M.R.C.S.  
1894—95 PROF. F. GOTCH, M.A., F.R.S.  
1895—96 PROF. R. J. HARVEY GIBSON, M.A.  
1896—97 HENRY O. FORBES, LL.D., F.Z.S.  
1897—98 ISAAC C. THOMPSON, F.L.S., F.R.M.S.  
1898—99 PROF. C. S. SHERRINGTON, M.D., F.R.S.  
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.  
1900—1901 PROF. PATERSON, M.D., M.R.C.S.  
1901—1902 HENRY C. BEASLEY.  
1902—1903 R. CATON, M.D., F.R.C.P.  
1903—1904 REV. T. S. LEA, M.A.  
1904—1905 ALFRED LEICESTER.  
1905—1906 JOSEPH LOMAS, F.G.S.  
1906—1907 PROF. W. A. HERDMAN, D.Sc., F.R.S.
- 

### SESSION XXII., 1907-1908.

#### President :

W. T. HAYDON, F.L.S.

#### Vice-Presidents :

PROF. W. A. HERDMAN, D.Sc., F.R.S.

JOSEPH LOMAS, F.G.S.

#### Hon. Treasurer :

W. J. HALLS.

#### Hon. Librarian :

JAMES JOHNSTONE, B.Sc.

#### Hon. Secretary :

JOSEPH A. CLUBB, M.Sc.

#### Council :

HENRY C. BEASLEY.

R. CATON, M.D.

M. CUSSANS, B.Sc. (Miss).

OULTON HARRISON.

W. S. LAVEROCK, M.A., B.Sc.

DOUGLAS LAURIE, M.A.

A. LEICESTER.

R. NEWSTEAD, M.Sc., F.L.S.

J. H. O'CONNELL, L.R.C.P.

JOSEPH PEARSON, D.Sc.

T. C. RYLEY.

L. R. THORNELY (Miss).

## REPORT of the COUNCIL.

DURING the Session 1907-1908, there have been seven ordinary meetings and one field meeting of the Society. The latter was held in conjunction with the Manchester University Biological Society, the Liverpool Geological Society and others.

By the death of Mr. T. C. Ryley the Society has lost one of its oldest members, and one who, from the year of his election, took an active interest in the affairs of the Society, both as a member of the Council and latterly as the Honorary Treasurer, which position he occupied for a period of ten years. The Council desires to record its appreciation of his services, and of the great loss sustained by his death.

The communications made to the Society at the ordinary meetings have been representative of almost all branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

By invitation of the Council, Prof. R. H. Yapp, M.A., of the University of Wales, Aberystwyth, lectured before the Society, at the May Meeting, on "The Vegetation of the Fenland."

The Library continues to make satisfactory progress, and additional important exchanges have been arranged.

The Treasurer's statement and balance-sheet are appended.

The members at present on the roll are as follows:—

Ordinary members	-	-	-	-	-	-	56
Associate members	-	-	-	-	-	-	3
Student members, including Students' Section	-						55
Total	-						<u>114</u>



## SUMMARY of PROCEEDINGS at the MEETINGS.

---

The first meeting of the twenty-second session was held at the University, on Saturday, October 12th, 1907.

The President-elect (W. T. Haydon, F.L.S.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1906-1907 (see "Proceedings," Vol. XXI., p. viii.) was submitted and adopted.
2. The Treasurer's Balance Sheet for the Session 1906-1907 (see "Proceedings," Vol. XXI., p. xx.) was submitted and approved.
3. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, Prof. Herdman, D.Sc., F.R.S., and Joseph Lomas, F.G.S.; Hon. Treasurer, W. J. Halls; Hon. Librarian, James Johnstone, B.Sc.; Hon. Secretary, Joseph A. Clubb, M.Sc.; Council, H. C. Beasley, R. Caton, M.D., Oulton Harrison, W. S. Laverock, M.A., B.Sc., R. Newstead, F.L.S., J. H. O'Connell, L.R.C.P., and Joseph Pearson, D.Sc.
4. Mr. W. T. Haydon, F.L.S., delivered the Presidential Address on "The Seed Production of *Pinus sylvestris*" (see "Transactions," p. 1). A vote of thanks was proposed by Mr. R. Newstead, seconded by Mr. T. C. Ryley, and carried with acclamation.

The second meeting of the twenty-second session was held at the University, on Friday, November 8th, 1907. The President in the chair.

1. Exhibition by the President of a large series of micro-photographs made in the preparation of the inaugural address on "*Pinus sylvestris*."
  2. Dr. J. H. O'Connell gave an account of the new Colour Photography, and exhibited a series of autochromes.
  3. Mr. W. D. Brown exhibited, with remarks, a collection of wind-etched stones.
  4. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 33).
- 

The third meeting of the twenty-second session was held at the University, on Friday, December 13th, 1907. The President in the chair.

1. Dr. H. E. Roaf briefly submitted a preliminary note on the digestive secretions of certain mollusca.
  2. Mr. J. Pearson, D.Sc., gave an interesting account of the Biological Station on Heligoland.
- 

The fourth meeting of the twenty-second session was held at the University, on Friday, January 17th, 1908.

1. On the motion of the President, the following Resolution was adopted in silence:—

"We, the members of the Liverpool Biological Society, wish to express our sorrow at the death of Mr. T. C. Ryley, and our deep sympathy and condolence with Miss Ryley and family in their bereavement. Some of us mourn Mr. Ryley as an intimate friend, and all bear testimony to his hearty kindness and ever ready helpfulness."

2. Mr. Oulton Harrison submitted a series of lantern slides illustrating living lepidoptera, made by Dr. Hugh Main.
  3. Dr. J. O'Connell gave an account and exhibited specimens of living South African amphibians.
  4. Mr. J. Johnstone, B.Sc., submitted the Annual Report of the Investigations carried on during 1907, in connection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 93).
- 

The fifth meeting of the twenty-second session was held at the University, on Friday, February 14th, 1908. The President in the chair.

1. Mr. H. C. Beasley contributed a note on some recent finds at Storeton, including some good impressions of *Equisetites keuperina*.
- 

The sixth meeting of the twenty-second session was held at the University, on Friday, March 13th, 1908. The President in the chair.

1. Mr. J. Pearson, D.Sc., submitted the L.M.B.C. memoir on "Cancer" (see "Transactions," p. 291).



The seventh meeting of the twenty-second session was held at the University, on Friday, May 8th, 1908. The Vice-President (Prof. Herdman) in the chair.

1. Prof. R. H. Yapp, M.A., of the University College of Wales, Aberystwyth, gave a lecture on the "Vegetation of the Fenland," illustrated by a beautiful series of lantern photographs.
- 

The eighth meeting of the twenty-second session was the Annual Field Meeting held at Hilbre Island, on Wednesday, May 29th, in conjunction with the Manchester University Biological Society, the Liverpool Geological Society and others. At the short business meeting held after tea, on the motion of the Vice-President (Professor Herdman) from the chair, Prof. Benjamin Moore was unanimously elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL  
BIOLOGICAL SOCIETY.

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SESSION 1907-1908.

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A. ORDINARY MEMBERS.

(Life Members are marked with an asterisk.)

ELECTED.

- 1888 Beasley, Henry C., Prince Alfred Road,  
Wavertree.
- 1903 Booth, jun., Chas., 30, James Street, Liverpool.
- 1894 Boyce, Prof., University, Liverpool.
- 1889 Brown, Prof. J. Campbell, 8, Abercromby Square.
- 1886 Caton, R., M.D., F.R.C.P., 78, Rodney Street.
- 1886 Clubb, J. A., M.Sc., HON. SECRETARY, Free Public  
Museums, Liverpool.
- 1905 Cussans, Miss M., B.Sc., Edge Hill Training College,  
Liverpool.
- 1903 Dixon-Nuttall, F. R., Ingleholme, Eccleston  
Park, Prescott.
- 1886 Gibson, Prof. R. J. Harvey, M.A., F.L.S.,  
University, Liverpool.
- 1902 Glynn, Dr. Ernest, 67, Rodney Street.
- 1903 Guthrie, Thomas, 8, Canning Street, Liverpool.
- 1886 Halls, W. J., HON. TREASURER, 35, Lord Street.
- 1901 Hanna, W., M.A., M.B., 30, Marmion Road,  
Liverpool.
- 1896 Haydon, W. T., F.L.S., PRESIDENT, 135, Bedford  
Street S.
- 1886 Herdman, Prof. W. A., D.Sc., F.R.S., VICE-  
PRESIDENT, University, Liverpool.

- 1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.
- 1897 Holt, Alfred, Crofton, Aigburth.
- 1902 Holt, A., jun., Crofton, Aigburth.
- 1903 Holt, George, 5, Fulwood Park, Liverpool.
- 1903 Holt, Richard D., 1, India Buildings, Liverpool.
- 1898 Johnstone, James, B.Sc., HON. LIBRARIAN, University, Liverpool.
- 1903 Jones, Sir Alfred L., African House, Water Street.
- 1903 Jones, Dr. Robert, 11, Nelson Street, Liverpool.
- 1894 Lea, Rev. T. S., M.A., St. Michael Penkevil Rectory, Probus, S.O., Cornwall.
- 1886 Leicester, Alfred, 148, Liscard Road, Liscard.
- 1896 Laverock, W. S., M.A., B.Sc., Free Museums, Liverpool.
- 1906 Laurie, R. Douglas, M.A., University, Liverpool.
- 1886 Lomas, J., F.G.S., VICE-PRESIDENT, 13, Moss Grove, Birkenhead.
- 1905 Moore, J. E. S., 25, Croxteth Road, Liverpool.
- 1905 Moore, Prof. B., University, Liverpool.
- 1905 Mountmorres, The Hon. Viscount, Institute of Tropical Research, The Museum, Liverpool.
- 1904 Newstead, R., M.Sc., A.L.S., School of Tropical Medicine, Liverpool.
- 1888 Newton, John, M.R.C.S., 2, Prince's Gate, W.
- 1904 O'Connell, Dr. J. H., 38, Heathfield Road, Liverpool.
- 1904 Pallis, Miss M., Tatoi, Aigburth Drive, Liverpool
- 1894 Paterson, Prof., M.D., M.R.C.S., University, Liverpool.
- 1894 Paul, Prof. F. T., Rodney Street, Liverpool.
- 1905 Pearson, J., D.Sc., Zoological Department, Liverpool.
- 1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.



- 1903 Rankin, J., 67, South John Street, Liverpool.  
1903 Rathbone, H. R., Oakwood, Aigburth.  
1903 Rathbone, Herbert R., C.C., 15, Lord Street,  
Liverpool.  
1890 \*Rathbone, Miss May, Backwood, Neston.  
1897 Robinson, H. C., Malay States.  
1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.  
1895 Sherrington, Prof., M.D., F.R.S., University,  
Liverpool.  
1886 Smith, Andrew T., 5, Hargreaves Road, Sefton  
Park.  
1903 Stapledon, W. C., 2, Marine Park, West Kirby.  
1903 Thomas, Dr. H. Wolferstone, School of Tropical  
Medicine, Liverpool.  
1903 Thomas, Dr. Thelwall, 84, Rodney Street,  
Liverpool.  
1905 Thompson, Edwin, 1, Croxteth Grove, Liverpool.  
1889 Thornely, Miss L. R., Nunclose, Grassendale.  
1903 Timmis, T. Sutton, Cleveley, Allerton, Liverpool.  
1888 Toll, J. M., 49, Newsham Drive, Liverpool.  
1891 Wigglesworth, J., M.D., F.R.C.P., County Asylum,  
Rainhill.  
1896 Willmer, Miss J. H., 20, Lorne Road, Oxtan,  
Birkenhead.

## B ASSOCIATE MEMBERS.

- 1903 Tattersall, W., B.Sc., Marine Lab., Moyard,  
Letterfrack, Co. Galway.  
1905 Harrison, Oulton, Denehurst, Victoria Park,  
Wavertree.  
1905 Carstairs, Miss, 39, Lilley Road, Fairfield.

## C STUDENT MEMBERS.

- Adams, A., Zoological Department, University.  
 Arnett Dear, A., Edgeworth, Bebington.  
 Bishop, G. S. A., 4, Richmond Terrace, Everton.  
 Bramley-Moore, J., 138, Chatham Street.  
 Clothier, H. M., Zoological Department, University.  
 Greenwood, Miss F. V., Edge Hill Training College,  
     Durning Road.  
 Hudson, Miss K. B., University Hall, Beech Street.  
 Ponsonby, Miss F., Edge Hill Training College, Durning  
     Road.  
 Scott, Miss D., B.Sc., University Hall, Beech Street.  
 Shipperbottom, Miss L., Edge Hill Training College,  
     Durning Road.  
 Summers, Miss B., Edge Hill Training College, Liverpool.

## UNIVERSITY STUDENTS' SECTION.

*Chairman* : J. Davidson, B.Sc.

*Hon. Secretary* : A. Nicholls, (Miss) B.Sc.

*Members* :

- A. Owen, G. Mitchell, J. Davidson, A. Kenyon, A. Nicholls,  
 D. V. M. Moss, E. Hirst, E. Bury, E. Stopford,  
 M. Cheetham, R. G. Barlow, E. Bland, H. G. Jackson,  
 F. Uttley, F. Wilkinson, D. Lawson, O. Baier, A. B.  
 Dixon, M. M. Heap, H. P. C. de Silva, M. A. Molyneux,  
 H. Seddon, F. M. B. Price, M. Scott, M. F. C.  
 Southerst, L. B. Watterson, A. L. Prescott,  
 E. Matthewman, M. L. Whitehurst, K. Winston,  
 T. A. Smith, A. Lee, J. H. Mather, J. P. Thierens,  
 A. I. Wildman, E. M. Blackwell, A. Lennon, E.  
 Horsman, R. Lee, E. Beddoes, C. W. Dixon, B.  
 Williams, C. S. Baxter, L. E. Forster.

## D HONORARY MEMBERS.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du  
brocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Claus, Prof. Carl, University, Vienna.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

Solms-Laubach, Prof.-Dr., Botan. Instit., Strassburg.



# THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr.

IN ACCOUNT WITH W. J. HALLS, HON. TREASURER.

1907, Oct. 1st to Sept. 30th, 1908.

To Tea and Attendance at Meetings .....	£	s.	d.
" Attendance and Working Lantern .....	4	2	6
" Assistant Librarian (Honorarium) .....	0	17	6
" Travelling Expenses, Special Lecturer .....	5	5	0
" Postage and Carriage of Volumes .....	0	17	0
" Hon. Secretary's Expenses (postages, &c.) .....	5	9	4
" Messrs. Tinling & Co. ....	3	7	6
" Balance in Bank .....	40	0	0
	5	5	9
	<hr/>		
	£65	4	7

1907, Oct. 1st to Sept. 30th, 1908.

By Balance of last Account .....	£	s.	d.
" 19 Subscriptions .....	19	8	1
" 11 Arrears .....	19	19	0
" Subscriptions in advance .....	11	11	0
" 2 Associate Members at 10/6 .....	1	1	0
" Inset—Dr. Graham Renshaw .....	1	1	0
" Students' Section .....	1	1	4
" Sale of Volumes .....	6	10	6
" Petty Cash re-paid .....	3	2	7
" Bank Interest .....	0	9	1
	<hr/>		
	£65	4	7

*Audited and found correct,*

JOSEPH LOMAS.

LIVERPOOL, October 1st, 1908.

TRANSACTIONS  
OF THE  
LIVERPOOL BIOLOGICAL SOCIETY.





INAUGURAL ADDRESS  
ON  
THE SEED PRODUCTION OF  
*PINUS SYLVESTRIS*.

By W. T. HAYDON, President.

First, let me thank you for the honour you have deemed wise to confer upon me; I most heartily appreciate your kindness, but have more than vague doubt as to the wisdom of your selection. You have elected me to what must always be a difficult post for the amateur to fill, but more so when called upon to follow so brilliant a scientist as our esteemed friend Dr. Herdman.

It is not, however, for me to apologise, but to act; to do my best is all I can promise, and that I do right heartily. With regard to the subject of my address this evening, while fully aware that Presidential addresses are generally concerned with generalities and summarizings, I have ventured to take a definite subject—a subject to which I have devoted some considerable time—in the hope that it may prove acceptable and useful.

The Saturday afternoon and the evening walks, the holidays, and the spare moments of a busy life, have been devoted during the past six years—for the most part—to a study of the seed production of *Pinus sylvestris*. Some details of that study I have pleasure in bringing before you this evening. The subject has been studied both macroscopically and microscopically; the former in the woodland, the latter in the laboratory upon material collected and prepared by myself.

To give in detail all the observations made would

occupy far too much time, and serve no useful purpose, seeing that so much of it would be but a repetition of that which is already well known; as it is, I fear I have little or nothing new to record.

During the six years, 328 visits have been made to pine woods and pine trees in various places. They have been made at all seasons, even including times of severe frost, and at all hours, both day and night. 794 separate collections of material have been made, and in every instance it was "fixed" at once upon the spot. Several thousand ovules in various stages of development have been sectioned. Of these, special study has been made of 653, containing a total of 2,442 archegonia, their condition being at or about the period of fertilisation, and upon these the remarks that follow concerning fertilisation are based.

It will be my endeavour to lay before you, as accurately as may be, the observations made, but if at any time I depart from observed facts to the regions of speculation, or to the mere expression of opinions, kindly take such speculations or expressions for what they are worth, *cum grano salis*, or, if you will, *cum magno grano salis*. I trust, however, you will be able to consider any opinion expressed as having some—if not a sufficient—basis in the observed facts to warrant it.

The object of my work has been to trace as minutely as possible the entire process of seed production, beginning with the inception of the micro- and megasporangia, and ending with the fully developed seed. To say that the work is far from complete is to give but a faint idea of the numerous gaps yet to fill, and the many problems encountered that still remain unsolved. As presented to you this evening it must be regarded as a brief summary rather than as a detailed account.

The number of sound seeds enclosed in a fully developed cone of *Pinus sylvestris* but meagrely represents the enormous reproductive possibilities with which it was originally endowed. The young cone contained the potencies of some 1,500 pro-embryos, the mature cone yields only some 10 to 20 seeds. With so prodigal a provision for seed production this poor result seems out of all proportion, and we naturally ask: To what adverse influences then, are the possibilities contained in the young cone subjected, whereby such untimely disaster is brought about? To give a sufficient reply we must possess a knowledge of the reproductive organisation in all its details, we must know the minute structure and the functions of the various parts engaged in this wonderful process, we must know the history of their development, and the environment of the parts concerned during that development, and we must, further, be acquainted with the history of their relation to the outer world.

If a tree of *Pinus sylvestris* be examined during the winter it may readily be noticed that its branches bear buds, small cones, large unopened cones, and probably some old cones the scales of which are wide open. A closer examination will reveal the fact that the buds are of three kinds, namely, vegetative, microsporangiate, and megasporangiate; these may readily be distinguished the one from the other; the vegetative bud is relatively long and of small diameter at the base, tapering thence to a point; the microsporangiate is relatively shorter, thicker at the base, and its tapered form is rounded in outline; the megasporangiate bud is not tapered, its upper portion is more or less swollen, the amount depending upon the number of strobili it encloses, one, two, three, or occasionally four. Immediately behind some of these apical buds will be found one or more small cones—female

strobili—measuring about 10 mm. in length, and 8 or 9 mm. in diameter. These young cones are borne upon short, thick stalks, these latter being reflexed to an angle of about  $45^{\circ}$  with the axis of the branch bearing them, thereby inverting the cones and thus giving them protection against wet. Occasionally a cone may be found the stalk of which has not reflexed, being almost or quite upright; such an one will, on examination, prove to be but sparsely pollinated, or to have escaped that act altogether. At the base of the annual shoot bearing these buds and small cones will be found the large, unopened, fully developed seed-bearing cones; these vary considerably in form and size; some are almost globular, others somewhat barrel-shaped, the greater number, however, have semicircular bases, thence tapering away to a more or less blunt point. Intermediate forms are numerous. The globular form is the shortest, varying from 25 mm. to 40 mm. in length; those of taper form are longest, varying from 45 mm. to 55 mm. in length; cones 60 mm. long, and even longer are occasionally found.

As might be expected, these various forms and dimensions of the mature cones are to some extent modified by the number of sound seeds they contain, prolific cones being rounder in outline, and of larger diameter than those bearing but few or no seeds. At the base of the next annual growth may usually be found one or more open cones from which the seeds have been shed.

Here it may be well to note that the extent of each year's growth is permanently recorded, the amount being marked by the distance between each set of the lateral branches. The extent of this growth is dependent upon the character of the seasons, the nature of the soil, and upon the age of the tree. In the woods at Storeton, during the Autumn of 1903, I measured on one hundred and



twenty-five branches the annual growth of the previous five years. The mean was as follows:—

Year 1899, growth 104 mm.; 1900, 102 mm.; 1901, 112 mm.; 1902, 115 mm.; 1903, 108 mm.; the average of the five years being 108 mm.

Since then I have counted 200 branches, taking on each occasion measurement for five years, the details I omit, the mean comes out rather less than 106 mm.

Returning now to the series of buds and cones, we note that they represent certain definite stages in the growth and development of the organs of reproduction.

Our brief glance has made it apparent that this growth and development are spread over a considerable period of time, and a careful study shows that from the initiation of the buds to the dispersal of the ripe seeds, nearly three years elapse. This long period is divided naturally into four seasons. The first—June to October—being occupied with the production and growth of the various buds; the second—March to October—with the development and maturation of the pollen, the organisation of the embryo-sac, and the preparation of the nucellus of the ovule for the reception of the pollen, closing with the shedding of the pollen, and the consequent pollination of the prepared ovules. The third season—March to October—sees the renewed growth of the male gametophyte, the preparation of the female gamete for the reception of the male gamete, the act of fertilisation, the development of the embryo, and of the seed. The fourth season—Spring—sees the final act, in the opening of the scales of the matured cone, and the dispersal of the ripened seed.

Before taking our study in some detail, it will be convenient to make a brief examination of the ripe cones. If a dozen or so of ripe, but unopened cones be put

into a warm, dry place, all the upper scales of most of them will open, a few may open on one side only, and possibly one or two will remain closed. At the base of some of the scales of a fully opened cone there will be found two seeds, at the base of others, one only, while the greater number of the scales will be found giving shelter to seedless wings. It will be noticed that the seeds are of two colours, black and grey, the former are sound, the latter but empty husks.

The unsymmetrically opened cones will be found to contain seeds—sound or unsound—on the opened side only; the unopened ones, as might be expected, are practically empty. Although a large and well-formed cone has about fifty ovuliferous scales, and each scale is capable of bearing two seeds, it is very unusual to find one containing more than thirty seeds, from ten to fifteen is the more common number. These figures have been obtained from the tabulated record of nearly 500 cones.

The total number of scales upon a cone varies considerably, 94 being the highest, and 55 the lowest I have found. The number of ovuliferous scales varies also, but as these merge almost imperceptibly into the non-ovuliferous, they cannot so readily be enumerated, but taking those only about which there could be no reasonable doubt, the highest number I found was 53, and the lowest 34. Counting the scales upon 500 cones I found the mean per cone to be 75. The ovuliferous scales gave a mean of 48, thus providing for 96 possible seeds per cone. But, as already stated, the number usually produced being only 10 or 15, there is evidently an enormous wastage, to realise the extent of which it will be necessary to make some further observations.

This wastage, enormous as it is, is not comparable

with that so frequently seen in connection with certain fishes, where millions of eggs are without doubt foredoomed to failure—it is of an entirely different nature. With the fish eggs it is reasonable to suppose that if they become fertilised and nothing inimical happen, every egg may become a fish; not so, however, the Pines. In the first place although each archegonium usually produces four pro-embryos it is only possible that one of these can arrive at maturity. In the second place we note that each ovule contains about four archegonia, one only of which can possibly succeed. This means that supposing the four archegonia of an ovule be fertilised—it frequently happens—there will be sixteen pro-embryos formed, one only of which can possibly produce a seed.

This abundant provision of female potencies is exceeded—probably many thousands of times—by that of the male, but it is obviously of a different character.

What may be the significance of these peculiar provisions on the female side for the perpetuation of the species I do not know, but their existence appears to me to explain some of the many difficulties that are encountered in the attempt to work out the embryogeny of the Pines.

From the foregoing it is obvious that seed production in *Pinus sylvestris* is subject to many vicissitudes, and that any study made of it must bring the investigator into contact with many conditions of failure, due to disease, environment, enemies, abnormalities, etc. These failures are evident, as changes in structure, arrested growths, and alterations of sequence. The student has, therefore, to be on constant guard lest the abnormal be mistaken for the normal. Examples of this will be noted as we proceed.

Having now secured a general outline of the course

of events, we will proceed to consider the development step by step.

With the vegetative buds we are not concerned, and the microsporangiate buds may be disposed of in a brief sentence. They are recognisable as buds about the end of May; as a rule they are borne upon branches differing somewhat from those bearing the megasporangia; the internodes are shorter and slighter, the branchings are more numerous and clustered, they have thus a bushy character, producing conditions well adapted to the dispersal of the ripe pollen. These specialised branches are usually in groups, and usually at the lower part of the tree. The buds continue growth until the end of October, at which time the sporangia are found to be closely packed with pollen-mother-cells. Thus, well wrapped in the resinated bud-scales they remain at rest until the following spring.

The megasporangiate buds commence their development in May, but are not recognisable as such until the end of July, at which time their upper portion is seen to be distinctly swollen, indicating the presence of one or more young cones.

I think that sufficient evidence has been found to warrant the suggestion that the normal number of cones within a bud is probably four, for in numerous young buds examined there are certain definite areas of tissue in the act of breaking down, these areas occurring in positions where young cones might be reasonably looked for. They may, however, be initial leaves only—it is difficult to determine.

By the end of August the young cones are about .5 mm. in diameter, and the same in length, their shape already suggests that which they will ultimately assume; around the base there are a few protuberances.



By the end of September they are about .75 mm. in diameter and 1.0 mm. in length; the protuberances have increased in number and extend about half-way up the cone, at the end of October they cover the whole cone, thus faintly indicating the scales and bracts that are to be. They are now about 1.0 mm. in diameter and slightly more in length, some few are larger, while some are not more than .5 mm. in diameter, and of corresponding length. Growth has ceased and the winter rest commenced.

It is probable that just before the cessation of growth the archesporium is differentiated, but of this I have no evidence, as up to the present I have been unable to discover any trace of this cell.

Coulter and Chamberlain quote Strasburger as having demonstrated for *Larix* that the archesporium is differentiated very early in one or more hypodermal cells, and that *Thuja*, *Pinus sylvestris*, and *P. Pumilio* are essentially similar. These authors, while admitting that the probabilities are largely in favour of this statement, make it quite clear that they have been unable to substantiate it. Whatever its origin, it is evidently difficult to distinguish, and but for some fortunately oriented section might be quite easily overlooked.

About the second or third week of March in the following year, awakened into activity by the genial spring-time warmth, cell-division and consequent growth are renewed, and the numerous protective bud-scales begin to open.

The history of the development of the microspores is now so well known that a brief sketch of events will suffice. The microsporangia, as we have already noted, went to rest for the winter packed with spore-mother-cells. About the second week in April these mother-cells are

ready for division, a week later tetrads are formed; sometimes, however, two cells only result from this division. During the last week of the month the balloon-like appendages become well advanced, and a little later the spores leave the mother-cell. About the second week in May the spore divides, the resulting nuclei are apparently alike, but the cells formed are very different, for immediately after division the cell towards the rounded end of the spore begins to disintegrate, and speedily becomes a flattened mass against the wall; the large cell divides a second time, and again one of the resulting cells at once breaks down and becomes flattened upon the other.

Coulter and Chamberlain regard it "reasonable to suppose that these two evanescent cells represent a vestige of the vegetative tissue of the gametophyte, and that they may be called properly vegetative cells."

A third division follows, again cutting the spore into two unequal sized cells, the smaller of the two—lenticular in shape—lying immediately below those previously cut off, this is the generative cell, the forerunner of the sperms; the larger of the two is the tube cell. The pollen grains are now ready for distribution.

On the first bright sunny day at the end of May the sporophylls open, and should there be the slightest breeze the mature pollen is discharged in great profusion. The buoyancy given to the grains by the balloon-like appendages enables them to be carried hither and thither by the slightest movement of the air. As with all anemophilous plants, the bulk of the pollen is scattered to waste, a small proportion only finding its way to the open scales of the female cones.

Cell division and the growth of the megasporangia are renewed in the following spring, generally during the last week in March. Growth is rapid, for early in the

second week in April, the ovuliferous scales and their bracts are well defined. About the first week of May, the first indications of the ovules appear, the nucelli and micropyles being now readily distinguished.

About three weeks later—end of May—a cell somewhat larger than its fellows will be observed near the base of the nucellus, this is the megaspore mother-cell. In the course of a few days it is surrounded by two or three concentric layers of cells differing considerably from the other cells of the nucellus, the outer layer being in course of disintegration.

During the initiation of the megaspore mother-cell other changes are taking place: the apex of the nucellus breaks down, and thus there is formed a somewhat cup-shaped depression, well adapted for the reception of the pollen, it forms in fact the equivalent of the stigmatic surface of the Angiosperms. The superficial cells of this depression appear to act as secretionary glands, and to pour forth a slightly viscid fluid, this latter mingling with the discharged contents of the disintegrated cells, flows into, and fills to overflowing the cavity of the open micropyle immediately below.

The young cone, which is of a purple-brown-red colour, is now fully prepared for the reception of the pollen; it stands almost erect, its opened scales give entrance to a cavity somewhat larger at the base than at the mouth, and in which the inverted ovules are situated, easy access is thus given to the pollen, and should any grains find their way between the scales they readily fall to the bottom. Here they become entangled in the viscid fluid, which gradually disappearing, either by evaporation, or by absorption into the nucellus, results in the grains being drawn into the micropyle and deposited upon the cup of the nucellus.

At the time of pollination the micropyle is a very short tubular opening immediately surrounding the apex of the nucellus; upon this opening there are two projecting walls, these stand with their faces perpendicular to the plane of the scale, one towards the outer side of the scale, the other opposite. The outer wall bears upon its inner face, and at its base, a small dome-shaped projection, the other has a plane surface. This short micropyle increases in length considerably as growth proceeds. Immediately the pollen reaches the nucellus the projecting walls of the micropyle close in, the outer, moving slightly in advance of the other brings its dome-shaped projection down upon the enclosed pollen grains and forces them into close contact with the nucellar surface; the opposite wall now closes, and lapping itself over the other secures it firmly (fig. 1). Shortly afterwards the hypodermal cells of the inner walls of the tube of the micropyle elongate transversely, continuing growth until they meet and close the passage; this elongation does not, however, occur in every ovule (fig. 2).

The protection of the nucellus and its precious contents is, however, not yet complete. The ovuliferous scales which opened to admit the pollen now close at their upper edges, and certain epidermal cells of the inner faces of the same scales function as glands (fig. 2), these pour into the cavity—closed at its upper edge—a copious supply of gummy resin which flowing over the micropyle effectually seals it; this exudation frequently fills the cavities to overflowing, appearing at the surface of the cone as a greyish granular deposit.

With the closing of the scales the stalk of the cone begins to slowly bend outward, until at the end of some 10 or 14 days the cone becomes inverted, and at an angle of about  $45^{\circ}$  with the axis of the branch. During the last



few days a change has been taking place in the colour of the cone, the purple-brown giving place to that of green.

By this time—about the second week of June—the megaspore mother-cell has grown considerably, and has become of an oval shape with its longest diameter about 55 microns, and its shortest diameter about 28 microns. It passes into the spirem stage, the reduction division follows, and thus is initiated the gametophyte. Of the two cells resulting from this division, that toward the apical end of the nucellus immediately begins to break down, the other after further growth again divides, again the cell nearest the apex breaks down; this process is repeated yet once again, with the result that there are present on or about the 1st of July one functional megaspore and the remains of three others still undergoing disintegration (fig. 3).

This rejection of these three cells is remarkably like the rejection of the polar bodies during the maturation of the eggs of the vertebrates; occasionally, however, two or more megaspores function, giving rise—of course—to a corresponding number of gametophytes. Hofmeister records the very interesting case of a tree, in a marshy spot in the Botanical Garden at Leipzig, whose ovules mostly contained two embryo-sacs—gametophytes. I have one example with two gametophytes, and one with five gametophytes. In this latter case it is evident that one at least of the four megaspores must have divided once again to produce the five, and that they all persisted. As might be expected, the resulting gametophytes are but very poorly developed.

The zone of special tissue immediately surrounding the megaspore has increased, there being now about five concentric layers of the loosely aggregated delicate-walled cells, this zone being enclosed by another series of

concentrically arranged tabular cells apparently disintegrating; the inner zone must, I think, be regarded as the equivalent of the tapetal cells of the pteridophytes.

Although as already noted the pollen grains are deposited upon the nucellus about the end of May, their tubes do not commence growth until a month later—about 1st of July—the time coinciding with the advent of the functional megaspore. The tube nucleus passes immediately into the developing tube, leaving the generative cell still attached to the wall of the pollen grain. By the 1st of August the generative cell has undergone some slight modification, being now nearly globular in shape; it is about 18 microns in diameter, and its nucleus 8 microns in diameter. In this condition it passes later to its winter rest.

By the end of July the tubes have grown into the nucellus to a depth of some five or six cells, frequently having given off two or three branches, thus securing safe attachment, and the means of acquiring an ample food supply, these branches acting as haustoria.

About the same time the megaspore has reached a diameter of about 90 microns, and the spongy tapetal area has extended considerably.

About mid-October, when the megaspore has reached a diameter of 120 microns, free nuclear division takes place; at the end of the month the megaspore—now better designated the gametophyte—is 130 microns in diameter, and contains from 16 to 64 free nuclei. Further growth is suspended until the following spring.

Near the middle of the following March we are at the commencement of the third season, and we enter upon the most interesting portion of this long history. For five and a half months the young cones, with their carefully protected contents, have been subject to the frosts and wet

of the winter season, but now, responsive to the warm sunbeams, the cells renew their marvellous activities of growth, multiplication, and function; they have much to do, for in three and a half months the small cone of some 10 mm. in length has to be built up into one of over 50 mm. in length.

About the 25th of March cell-division is taking place in all the various tissues, and one or two mitoses of the free nuclei of the gametophyte may take place before the 1st of April. These nuclei are 10 microns in diameter, and contain at this period one nucleolus; they are entirely parietal, being embedded in the thin cytoplasmic layer forming the inner lining of the young gametophyte. This layer, in a preparation, is approximately about the same thickness as the diameter of the free nuclei, viz., 10 microns; in the living condition it is much thicker.

The diameter of the gametophyte in the last week of March is about 150 microns. Owing to its delicate wall and large unsupported cavity it is difficult to secure a preparation free from collapse; osmic or corrosive I have found useful as fixing agents during this early period.

The tissue surrounding the gametophyte is very lax, with exceedingly thin and tender walls; its tapetal character at this period is very evident; its cells are dividing, and its extent is increasing rapidly. The nuclei of these cells are 13 microns in diameter, and when ripe for division are 22 microns. The pollen tubes have commenced a very slow growth into the nucellus, the cells of which are charged with an abundant food supply in the form of starch. The generative cell has grown to a diameter of 35 microns, its nucleus being 15 microns diameter: it is now preparing for division. This takes place during the second week of April; the resulting cells when first cut off are usually alike in size and appearance,

their nuclei are about 10 microns in diameter. As growth proceeds a change takes place: the cell nearest the tube, known as the body-cell, grows more rapidly than the stalk-cell, so that a week later, when they migrate into the tube, the stalk-cell nucleus is 17 microns diameter, and the body-cell nucleus 24 microns diameter. The tube nucleus is oval in shape, its two diameters in March being 18 microns and 13 microns; a month later, when the body and the stalk cells migrate, its two diameters are 24 microns and 15 microns; at this period it is densely surrounded by starch grains.

By the second week of April the cells surrounding the gametophyte have become so lax that they can scarce be described as forming a tissue; the gametophyte still remains a hollow globe containing parietal nuclei only. The ovule has grown to a length of 1.3 mm.; the nucellus is about 30 cells deep from its apex to its junction with the tabular cells which form a wall enclosing the lax tissue surrounding the gametophyte, nearly half of this depth is occupied by the pollen tubes and their branches.

At this period there is evidence of great mortality amongst the young gametophytes; in fact this may be said of the whole period commencing with the organisation of the megaspore in July till about the middle of the May following, when the archegonia are initiated. During this interval many ovules may be found in which the gametophyte is in course of disintegration, others in which no trace of one can be discovered. The ultimate fate of such ovules can only be conjectured; doubtless in some, growth is at once arrested, such would possibly account for the small brown "specks" that are found during the third season occupying the place of ovules; others may continue growth and become the empty husks that are found in ripe cones.



At this period it is not uncommon to find abortive pollen grains; some few have not developed a tube, others have grown a tube, but the body- and stalk-cells have come to grief, thus rendering them sterile.

Ovules may occasionally be found in which the whole of their tissue is breaking down: these have not been pollinated, or if pollinated the pollen has not germinated.

By the third week of April the gametophyte has reached a diameter of over 300 microns; its nuclei are still parietal—they may have divided once since their last division in March. It is not until the second week of May that these nuclei divide rapidly and begin to fill the cavity from the parietal layer inwards; some days before the cavity is filled a layer of cells is organised at the nucellar end of the gametophyte distinctly different from those elsewhere, their walls are thicker, their cytoplasm denser, and their shape more cubical; this layer of cells gives rise to the archegonia (fig. 4). It usually becomes four cells deep before the archegonia are sufficiently large to be recognised as such; they grow rapidly, and soon occupy as much space as any four of the adjoining cells; they now divide, and a small cell is cut off at the dermal end, from which will arise the neck-cells of the archegonia (fig. 5). At this stage the archegonia are about 55 microns in length, and 22 microns wide.

The number of archegonia initiated appears to be either four or eight, for in fifteen gametophytes in which the archegonia are very young, and in which they can readily be counted, there are nine with four archegonia and six with eight archegonia. Here are definite numbers, suggesting that they arise from one mother-cell, the difference being one division only. All the archegonia initiated certainly do not reach maturity, for in various stages of their development they may be found in



the act of breaking down. Moreover, out of the 653 ovules I have specially examined with reference to fertilisation, 487 of them contain from four to no archegonia, and the remaining 166 have from eight to five archegonia. In the 487 ovules the archegonia are distributed as follows:—

Without archegonia	-	-	7
With one archegonium	-	-	7
With two archegonia	-	-	63
With three archegonia	-	-	231
With four archegonia	-	-	179

In the 166 the archegonia are distributed as follows:

With five archegonia	-	-	114
With six archegonia	-	-	38
With seven archegonia	-	-	10
With eight archegonia	-	-	4

The first group of figures favours the suggestion that many gametophytes initiate four archegonia, but the second group appears at first sight decidedly against the supposition that they have arisen from an initial start of eight; but it must not be forgotten that it is impossible for one gametophyte to produce more than one embryo, although it may originally contain the potencies of 32 pro-embryos, and therefore it will be to the advantage of the gametophyte to husband its resources as early as possible.

Be this as it may, it is remarkable that of 15 young gametophytes, six contain eight archegonia, and that in 653 mature gametophytes only four were found containing eight archegonia each. In one of these the archegonia are arranged in two tiers; a tendency to this arrangement is frequently observed where the number exceeds four.

At this period—the middle of May—the gametophyte is practically free, floating as it were in a thin plasm

which fills the space recently occupied by the cells I have ventured to regard as tapetal, fragments of these latter are numerous; there are still two or three layers of the tabular cells bounding the cavity; they are, however, rapidly disappearing, the last few days of their existence being characterised by the phenomena of unequal amitotic division, and polynucleated cells.

The cells immediately surrounding the young archegonia, and which constitute the four layers, are known as jacket cells; they form an almost complete envelope or jacket around each archegonium. They persist and function until the pro-embryos are laid down.

By the last week of May the central cells of the archegonia have grown considerably, being now about 250 microns in length and 100 microns in diameter; the nuclei are about 32 microns in diameter, and are at the apex of the cell immediately beneath a single row of four neck cells. In a few days—first week of June—the central cells are nearly 400 microns long; the nuclei have correspondingly increased in size; the single layer of neck cells have divided, there being now two layers of four cells each; the endosperm of the gametophyte has extended at the apical end, leaving the neck cells at the base of a short funnel-shaped tube. Growth proceeds rapidly, and about the end of the third week of June the nucleus of the central cell (it will be well now to deal with the individual) is ripe for division; it is now about 50 microns in diameter. It is still situate at the apex of the cell, the cytoplasm of which is vacuolated, usually one large central vacuole surrounded by a number of smaller ones (fig. 6). The ripe nucleus now divides, producing at the apical end what is known as the ventral canal cell, and at the other the egg cell. The former is a very small cell, which together with its nucleus at once commences to

degenerate, practically leaving the whole cavity of the venter free to the cytoplasm of the egg cell. The nucleus of this cell when first cut off is often very small—its size varies considerably—but it is usually about 50 microns in diameter ere it leaves the spindle. It at once passes to the centre of the egg, by which time it has acquired a diameter of about 100 microns; it is frequently 130 microns in diameter. By this time the cytoplasm of the egg has undergone a great change, its vacuolate condition has given place to one of compactness, it is for the most part finely granular; around the nucleus may frequently be seen dense threads radiating into the granular mass; immediately within the egg wall there are a number of globular bodies, somewhat nuclear like, known as “proteid vacuoles.” In the cytoplasm near the apex of the cell there is a distinct oval shaped cavity. The egg is now ready for fertilisation.

Here it will be convenient to refer again to the male gametophyte. We have already noted that the generative cell divides during the second week of April—about April 11th—giving rise to the body- and stalk-cells and that they pass from the grain into the tube a week or ten days later—April 21st. There appears to be, however, great latitude as to the time of their migration, for examples are found in which this has taken place so late as June 6th.

The body-cell divides to produce the sperms—gametes—during the third week of June. Since their fresh start in spring the tubes and their branches have grown but little, in fact the amount is frequently almost imperceptible; with the advent of the sperms, however, the growth of the tube proper is very rapid, for within a week—probably in two or three days—it has pierced the nucellus and entered the egg by way of the funnel-shaped

cavity above the neck cells. The sperms when initiated are about 15 microns in diameter; they grow rapidly, reaching maturity and a diameter of 28 microns to 30 microns before they have left the spindle.

Before proceeding to describe the act of fertilisation, it will be well to refer to one or two points of some importance. First with reference to the division of the generative cell. Dixon gives the time at which this occurs as towards the end of April, and as he found fertilisation took place at the end of May, the division was just a month before that event. Margaret C. Ferguson, in her exhaustive and accurate work upon *P. strobus* says that in *P. strobus* and *P. austriaca* "the stalk and the generative cell (body-cell) are formed as a rule before the approach of winter." That is during the *second* season. From the many preparations I have examined, I conclude that Dixon was quite right with regard to *P. sylvestris*, but his statement that very shortly after this the body cell divides within the grain—he so figures it—to produce the two sperms, I cannot confirm. I also think the dates given by him for the various phases are open to question: it looks as though he had got his material mixed.

The next point refers to the "proteid vacuoles." Whence come they? Without doubt they are derived from the jacket cells, which enclose the egg on every hand. It is the function of these cells to provide the food necessary to the growing egg. This is accomplished by their protoplasmic contents becoming reduced to a finely divided granular condition; in this state it passes through the perforated walls of the cells into the egg. The perforations are comparatively large and easy of demonstration, an aqueous solution of saffranin differentiating them quite strongly (fig. 7). Owing to the slight shrinkage of the egg cytoplasm, which generally occurs



even in the best "fixed" material, it is almost impossible to find the passage of the jacket cell contents taking place, but in some fortunate sections it may be seen.

That the proteid-vacuoles are derived from these jacket cells is supported by the fact that sooner or later in the development of the egg, the jacket cells become quite empty; further support is given, I think, by the fact that in ripe eggs, *before* fertilisation, karyokinetic figures are to be found in the cytoplasm; these appear to consist of spindles only, if there be any chromatin present it must be in small quantity; the figures are generally multipolar. I regard these as the result of lingering potencies still possessed by these, as yet, but slightly altered jacket cell contents (fig. 8).

The jacket cells appear to be very unstable in their nature, being subject to numerous abnormalities; the cells are often of huge dimensions, containing many free nuclei, these are produced both mitotically and amitotically, sometimes the two methods apparently taking place in the same cell (fig. 9).

Yet another point. When the ventral canal cell is cut off, the resulting nuclei appear exactly similar; that they are not, is proved by the fact that one of them at once breaks down. The two cells are generally considered as having been at some time in the past of equivalent size and function; the ventral canal cell is thus regarded as an arrested gamete.

I have found several archegonia in which the ventral canal cell might be regarded as abnormally large. Two have very large cells, similar to those described by Couffer and Chamberlain (one of them is shown in fig. 10). These authors think it possible that in some cases the ventral canal cell is fertilised rather than the egg; and further state that there are some grounds for believing that the

nuclei of the ventral canal cell and of the egg may fuse, suggesting what has been observed among animals in cases of parthenogenesis. With these statements I am inclined to agree, for I have several examples showing what appears to be the first division of the fertilised egg, and in which no trace whatever can be found of the entrance of a male gamete; notably, one where two eggs in juxtaposition bear not the slightest evidence of having been fertilised, both, however, appear in the condition of the first division after fertilisation. A remarkable feature in this case is the direction taken by the spindle in each egg, one being arranged parallel with the longer axis of the egg, the other at right angles to it (fig. 11). Chromosomes appear to be absent, at any rate the amount of chromatin present must be exceeding small. It is possible that these are examples of the uniting of the two nuclei, but there can be no proof.

Resuming: We have brought our history up to about the first of July of the third season. The egg nucleus is fully grown and ready for fertilisation (fig. 12), and the two sperms are at the end of the tube ready to be projected into the cytoplasm of the egg. A normal fertilisation is effected by the apex of the pollen tube, after penetrating the nucellus descending one of the funnel-shaped depressions in the apex of the endosperm; after crushing through the neck cells the wall of the tube fuses with the wall of the egg, the end of the tube ruptures, and the contents, consisting of the two sperms, the tube nucleus, the stalk nucleus, and the cytoplasm with its included starch, all pass with great rapidity into the egg, one of the sperms passes, probably, without interruption direct to the egg nucleus. The pollen tube does not, however, always take the normal and shortest way to the egg nucleus; it sometimes passes down outside the endosperm

to some distance below the archegonia, then bores in at the side and comes up through the base of the egg. Occasionally it bores down through the jacket cells between the archegonia and then enters the egg from the side.

Whatever route be taken, immediately the nuclei come into contact the wall of the egg nucleus is pushed in by the male gamete, until it becomes embedded flush with the surface of the female gamete. At the moment of contact, both nuclei shrink somewhat, a process which stops when fusion is complete; with other changes both nuclear walls disappear, and a spindle bearing 24 chromosomes is in evidence (fig. 13). The changes which take place in the interval between the embedding of the male gamete in the substance of the female gamete, and the presence of a spindle with chromosomes, are, according to all investigators, of a very remarkable and complex character. It is stated that no resting nucleus is formed, that the two nuclei pass independently into the spirem stage, and that it is only when on the spindle that the two groups of chromosomes become fused.

Margaret C. Ferguson describes in great detail the course taken in *Pinus strobus* for this interval, and gives 21 figures in illustration. From her very abundant and rich material she has selected a series of figures that certainly appear to follow each other in admirable sequence. In my poorer material—for there is in Miss Ferguson's work evidence of a far larger proportion of fertilised eggs than in that at my disposal—I have been unable to discover but a few phases that may possibly represent stages of development during this particular interval. None of them are in any way similar to those figured by her, and I am inclined to regard some of them at least as being abnormal. A wisp-like stage somewhat

similar to that figured by Chamberlain I have occasionally found, but nothing exactly like it.

That a fusion nucleus is not formed, I do not consider proved. In more than one instance I have found the nucleus of a fertilised egg having all the appearance of complete fusion, and one case at least, of which there can be no reasonable doubt (fig. 14). I hope later to decide this point. For the present I leave it here.

Whatever may be the course of procedure, the time taken is very short, for in two days the first division is complete, and about 24 hours later the resulting nuclei have again divided. These four nuclei are usually produced in the upper half of the egg, occasionally it may be about the centre; when first clear of the spindle they are about 40 microns in diameter; they at once pass to the base of the egg, impelled probably in some way by the fibres that soon invest them.

By the time the base is reached they appear to have increased somewhat in size; this, however, is difficult to determine owing to their very variable dimensions; although the average size of these when ready for division is about 55 microns, many are found much smaller, others much larger; they vary in fact between 40 and 70 microns.

The fibres investing the nuclei are exceedingly fine, but densely packed. They are now arranged in such a way that they appear to be vertical walls forming four open pockets, in each of which there is a nucleus, and as walls they have generally been regarded. That they are not walls is at once evident when the nuclei pass into the spindle stage of division, for at this time the fibres have disappeared, and no trace of walls can be detected. During this division transverse walls make their appearance upon the spindle in the usual way. While this division is in progress there has been a re-aggregation of



the vertical fibres, and before the transverse walls are complete vertical walls are initiated within the fibres, commencing on both sides of the transverse wall, gradually extending until the lower tier of nuclei are enclosed in four separate cells, and the upper tier are enclosed in four deep pockets, open to the cytoplasm above. Simultaneous division now takes place in the upper tier of free nuclei, and transverse and vertical walls are again formed; there are now two enclosed tiers and one open tier. The next and last division that occurs within the egg takes place in the lower tier. The preceding appears to be the normal course of development of the four pro-embryos within the egg.

This sequence of division, however, occasionally varies; instead of the second division taking place in the upper tier of nuclei, it sometimes occurs in the lower; and the third division may take place in the upper tier instead of the lower; I have excellent examples illustrating both varieties. What effect these apparently abnormal divisions have upon the further development can only be conjectured. Even though development continue, it is highly probable that it will be limited, and not result in the production of an embryo. I have many preparations in which this group of cells is disintegrating, and others with distinct abnormal development, one, for instance, in which the upper tier have grown into the egg as elongated cells, apparently suspensors!

While these five divisions have been proceeding other great changes have been taking place within the egg; its cytoplasm has been constantly renewed by the outpourings of the jacket cells, and as constantly used by the dividing cells, until when the sixteen cells are fully developed, the jacket cells are practically empty, and the egg cytoplasm is nearly all used up.

This cleavage of the egg into sixteen cells—twelve complete and four incomplete—is very suggestive of the segmentation which takes place in the fertilised eggs of the Metazoa. In *Pinus sylvestris*, however, the segmented egg provides for four embryos, and not for one only as in the Metazoa. It is possible that this peculiarity in the genus *Pinus* has been brought about to provide in some measure against the exigencies to which it has been subjected, exigencies that have compelled it to distribute over a period of three years that which is accomplished by some of its near relatives in the short time of a few weeks. It is just possible that at some time when conditions were more favourable, that only one embryo was provided for by this group of cells. Coulter and Chamberlain have found one example of *P. laricio* in which but one pro-embryo was proceeding from the group, and these authors state that such seems to be the normal behaviour of *Picea excelsa*.

Whatever be the explanation it is a point of curious interest.

Returning to these cells at the base of the egg: The lower group are destined to initiate four embryos. The next above are to carry the embryos into the midst of the rich food stuffs of the endosperm; this they do by becoming of great length, occasionally piercing straight into the cell mass below, but more frequently doubling back upon themselves several times. These long cells—suspensors—not only carry the embryo to the abundant food supply, but by reason of the large surface they present absorb it through their walls, and pass it on to their charges.

I have one example in which the embryos have gone round the adjoining egg, instead of into the endosperm below (fig. 15).

About a week after the uniting of the gametes the

embryonic cells and their suspensors are ready to penetrate the endosperm; this latter has become greatly modified, a cone-shaped mass of special tissue having been formed immediately beneath the group of archegonia. The cells of this tissue are specially organised for the production of starch and its subsequent preparation as food for the growing embryos, thus taking up the work hitherto performed by the egg and jacket cells.

The advancing suspensors pierce and corrode the cell walls in much the same way as did the pollen tubes on their passage through the nucellus. When the embryonic cells have been carried a short distance into the endosperm they commence growth, and should more than one egg be fertilised, a keen competition must ensue for supremacy. For instance, if four eggs have been fertilised—we have already noted that this frequently happens—there will probably be sixteen embryos struggling for a food supply sufficient only for one of them. As it is possible for only one of them to succeed in producing a normal seed, fifteen of them have to give way. Some few make but little headway, and soon become absorbed into the tissues of the survivors; others continue the struggle until development is fairly advanced, even a few surviving until late September. Generally, however, by this time, one has in some manner proved its superiority, and continues its progress alone to full development and maturity: this is reached at the end of October. The embryo, with its cotyledons (about seven), now enveloped with endosperm closely packed with starch for future food, passes to rest until the warm days of spring. It is a complete seed fitted with a wing whereby when liberated from the cone it may be borne to a congenial spot, where, if all goes well it will germinate, and finally become a tree like that from which it was shed.

To close without some reference to the chromosomes

would be to omit a most important result of the study. I have been fortunate in securing a very large number of mitoses in which the chromosomes can be studied and counted with ease. In the cells of the various tissues they are normally more or less U or V shaped. Occasionally they are found as short thick rods; these are probably abnormal, for they are found in abnormally large, or in ill-developed cells; these rod-like chromosomes are sometimes invested with a fluffy covering, having the appearance of a stick covered with penicillium or such-like fungus. I have one example of the rod-like chromosomes of peculiar interest, as in one section ten of the chromosomes are approximately in one plane, the adjoining section contains the other two. This is an abnormally large jacket cell (fig. 16). These jacket cells possess many peculiarities, and present many problems for solution.

There are 24 chromosomes in the cells of the sporophyte, and 12 in those of the gametophyte. They have been counted in a very large number of examples in both generations, and in no instance where a complete count was possible was any other number found. These numbers were found in abnormal forms also. In the sporophyte they have been counted in the leaves, stem, and the various tissues of the cone, in the first and following divisions of the fertilised egg, and in the developing embryo. In the gametophyte they have been counted in the micro- and macro-spores, the jacket cells, the cells of the endosperm, and in the central cell when cutting off the ventral canal cell.

And thus I bring the rough summary of a six years' work to a close. I have endeavoured to compress into as brief a space as possible the outlines of a vast and fascinating subject. I fear I have attempted too much, but hope that by the aid of the lantern slides you have been able to follow me.



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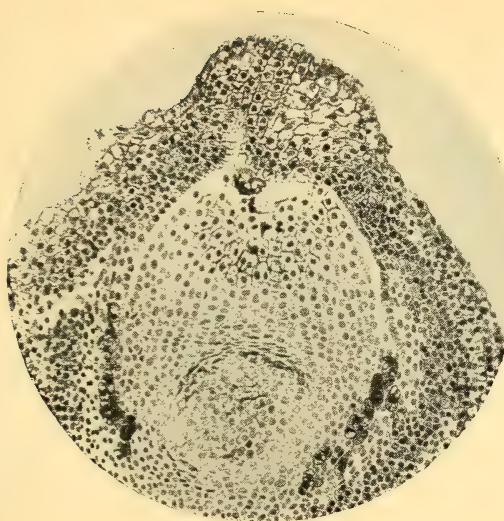


Fig. 1. Dome-shaped projection on wall of micropyle, after pollination. Cut in plane of scale.  $\times 96$ .

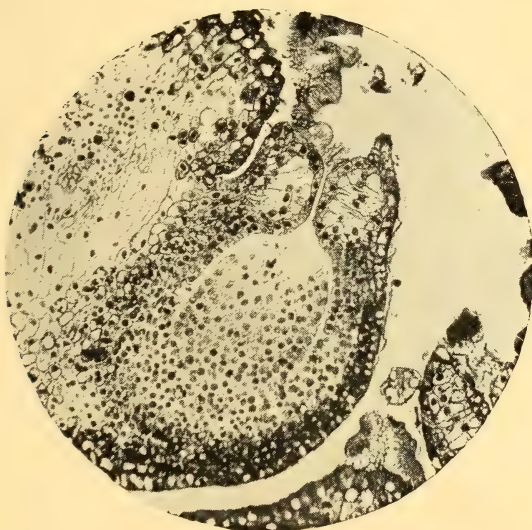


Fig. 2. The elongated hypodermal cells of the micropyle. The large cells at the top are glandular, and give rise to the gummy-resin which seals the micropyle. Cut perpendicular to scale.  $\times 96$ .

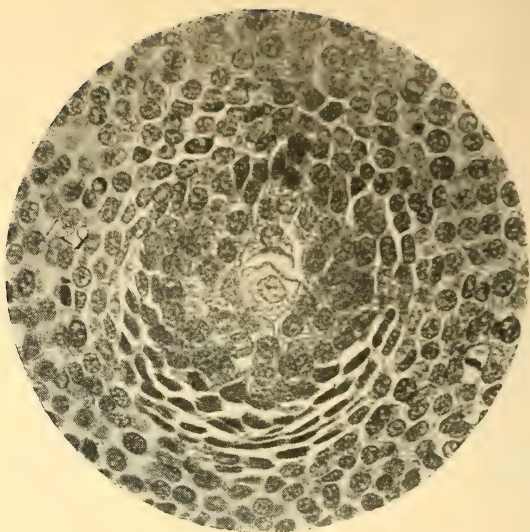


Fig. 3. The four megaspores, the lower one being functional, the others in course of disintegration.  $\times 280$ .

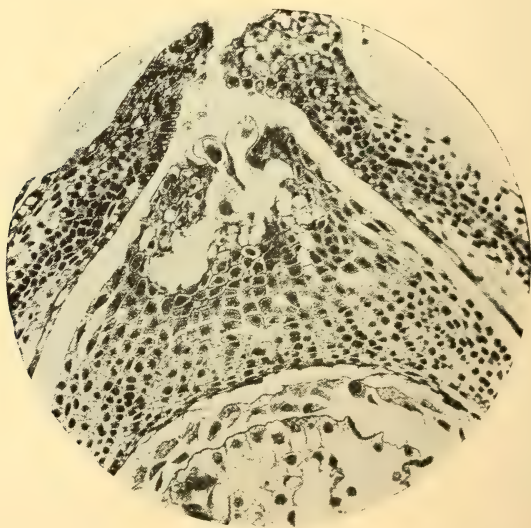


Fig. 4. The apex of an ovule, showing the micropyle with its dome-shaped projection, and the nucellus with pollen grains and their tubes. The lower portion shows the endosperm with the layer of cells from which are organized the archegonia. Between the endosperm and the nucellus are the breaking down cells of the tapetum layers.  $\times 96$ .

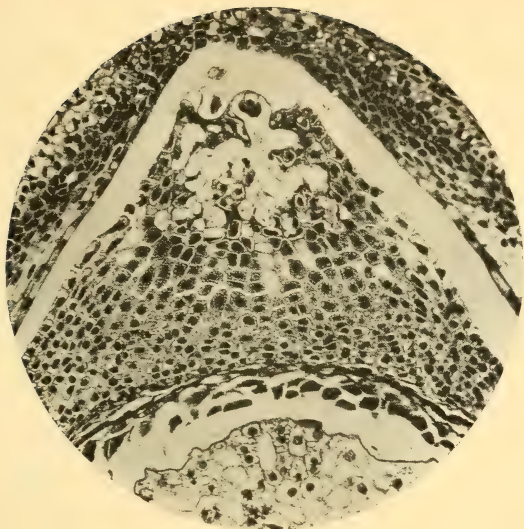


Fig. 5. A stage slightly in advance of Fig. 4. Young archegonia are organized at the apex of the endosperm.  $\times 96$ .



Fig. 6. An archegonium before the cutting off of the ventral canal cell. The cytoplasm is vacuolated. The nucleus is in the spirem stage. Immediately above the nucleus are the two tiers of neck cells, these latter being at the bottom of the funnel-shaped tube.  $\times 96$ .



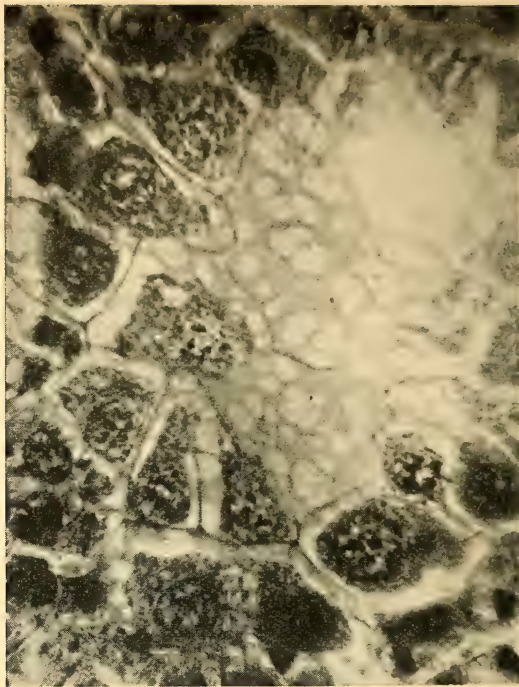


Fig. 7. Perforations through the walls of the egg and jacket cells.  
 $\times 460$ .

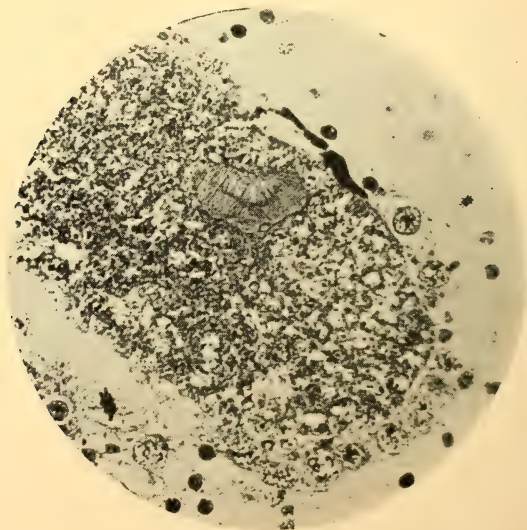


Fig. 8. Pluripolar mitosis in the cytoplasm of an unfertilised egg.  
 Active jacket cells are about the egg, and a patch of  
 exhausted jacket cells is seen above the mitotic figure,  
 $\times 96$ .

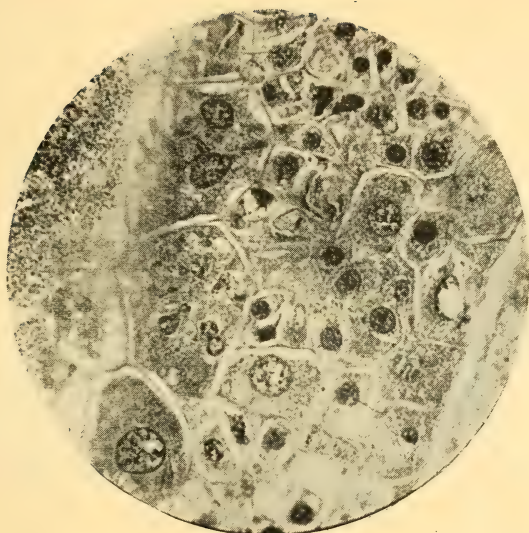


Fig. 9. Abnormally large jacket cells, multinucleated, the nuclei being formed mitotically, and amitotically. Perforations through the walls are seen to the left; the extreme left is the cytoplasm of the egg.  $\times 280$ .



Fig. 10. An abnormal ventral canal cell.  $\times 96$ .



Fig. 11. Two eggs apparently undergoing the first division, but in which no trace whatever can be found of the entrance of a male gamete.  $\times 96$ .

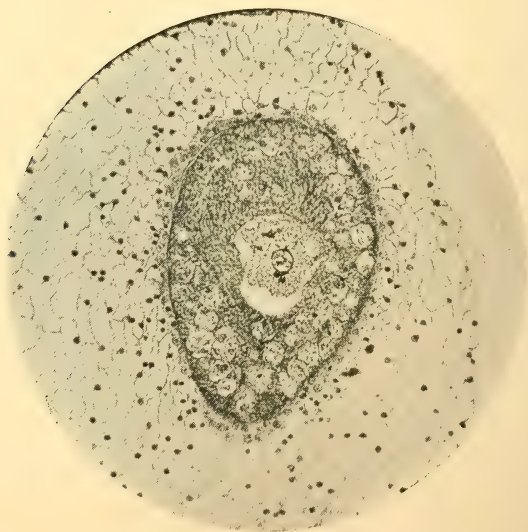


Fig. 12. A fully ripe egg. The cytoplasm contains the "proteid bodies." The nucleus is near the centre. This example contains an unusually large nucleolus.  $\times 96$ .



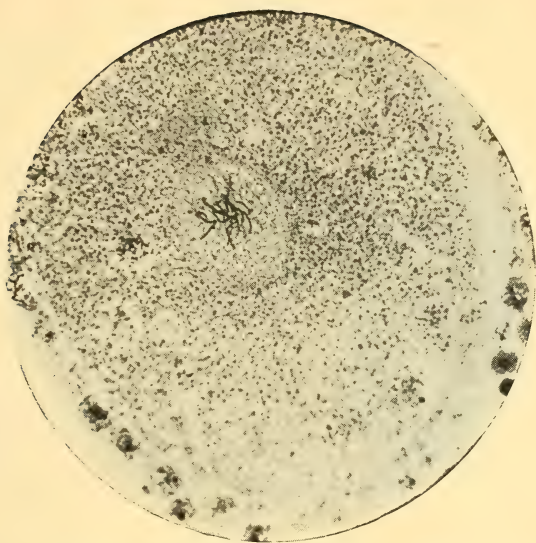


Fig. 13. A phase of the first division of the fertilised egg.  $\times 280$ .



Fig. 14. A zygote, or fusion-nucleus.  $\times 280$ .



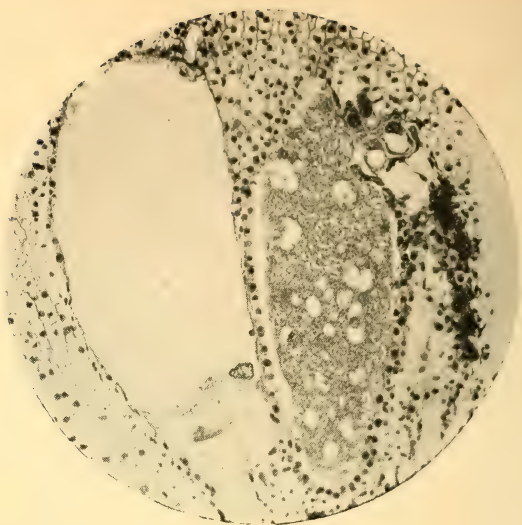


Fig. 15. A group of embryos are seen to the right, these instead of penetrating the endosperm below have passed round the adjoining egg. The course taken by them is clearly shown. The cytoplasm of the egg has been used up.  $\times 96$ .



Fig. 16. A large jacket cell containing twelve short rod-like chromosomes, ten of which are seen in the figure, the other two are in the adjoining section.  $\times 280$ .

THE  
MARINE BIOLOGICAL STATION AT PORT ERIN,  
BEING THE  
TWENTY-FIRST ANNUAL REPORT  
OF THE  
LIVERPOOL MARINE BIOLOGY COMMITTEE.

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THE pages of this Report will, I hope, show that the past year has been unusually full of work at our Biological Station, and especially at sea, where greater activity in submarine exploration has been displayed during the recent Easter and Summer vacations than was possible at

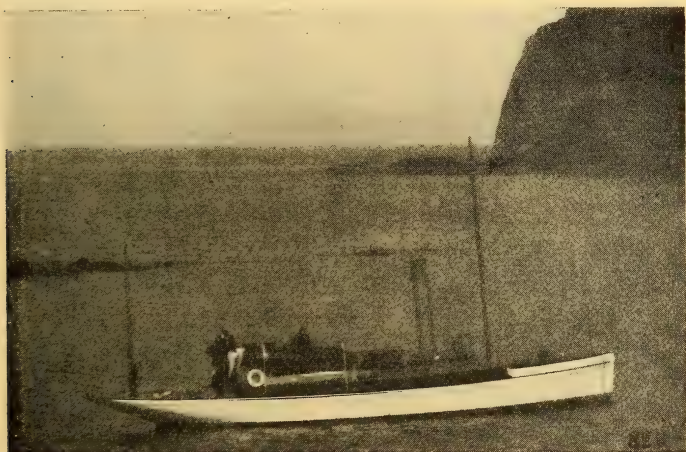


FIG. 1.—S.Y. "Ladybird."—From a Photo by E. E. UNWIN.

any previous period of our work. As an example, Mr. Andrew Scott, who is examining the tow-nettings, writes to me that over seven hundred samples have already been sent to him from the Irish Sea this season, a great increase on the number in any previous year. This improvement is mainly due to the advantage derived from having my small steam-yacht "Ladybird" available for use in dredging, tow-netting, and taking other observations in the deeper waters outside the bay.

As it is my desire and hope that this boat may contribute much to the scientific exploration of the Irish Sea in the future, it may be useful to readers of our reports that I should put on record here those particulars that give some idea of her size and fitness for work. She is a screw yacht, built of teak, by Summers and Payne, Southampton, in 1900, and measures about 70 feet over all by 12 feet beam and 6 feet draft. The cuts (figs. 1, 2, &c.) will show the fore-deck (with derrick, steam-capstan, and



FIG. 2.—Equipment of Plankton Nets, &c., on board the S.Y. "Ladybird." (Photo by Mr. R. OKELL).

reel of 200 fathoms of steel wire rope from which we work the trawl and dredges) and the long counter aft where we haul up the tow-nets and other smaller instruments. The tonnage is 36 (yacht measurement), the horse-power about 55, and the "Ladybird" will steam all day at  $8\frac{1}{2}$  to 9 knots on a small consumption of coal. Some of the other illustrations in this Report will show portions of the boat with some of her scientific apparatus in use.



We have worked with her this summer down to 76 fathoms in the deep channel between Port Erin and Ireland, where much exploration still requires to be done.

As on previous occasions, Mr. Chadwick's section appears below under the heading "Curator's Report," but I am, as usual, indebted to him, or to his weekly Reports, for much of the information given under "The Station Record" and elsewhere.

Mr. Chadwick has now completed the tenth year of his service as Curator of the Port Erin Biological Station, and he tells me that during that period 128 individual naturalists and students (some of them, of course, on many different occasions) have worked with him in the institution. I think I may venture to assure Mr. Chadwick, on behalf both of the Committee and also of all these workers, of our high appreciation of the careful and conscientious manner in which he has performed his duties, and of our cordial thanks for his constant helpfulness and cheerfulness, and for his successful endeavours to meet our manifold wants, both in the laboratory and on the shore.

It is a great pleasure to me to be able to congratulate Mr. Chadwick upon the mark of distinction which he has recently received in being elected, on December 19th, to the vacant Associateship of the Linnean Society of London. The A.L.S. is a real honour, and will be regarded by Mr. Chadwick's friends as a well-merited and welcome recognition of his long-continued good work as a naturalist.

The continued success of the Aquarium, and the increase in both the number and the appreciation of the visitors, is again most gratifying. An institution where nearly sixteen thousand summer visitors are shown the most interesting and beautiful of our sea-side animals



and plants in the living condition, amidst natural surroundings, with labels, pictures and other information, must, surely, be doing much to encourage nature-study and to foster an appreciation of biology. Over a thousand copies of the new edition of the illustrated "Guide to the Aquarium" have been sold to visitors during the present summer. This enlarged edition of the "Guide" is a booklet of about 80 pages and over 40 illustrations. Copies, at 3d. each (post free 4½d.), can always be obtained by writing to Mr. Chadwick, at Port Erin.

#### THE STATION RECORD.

Thirty-five naturalists and students have occupied the Laboratories for varying periods during the year, as follows:—

DATE.	NAME.	WORK.
Dec. 26th, 1906, to Jan. 8th, 1907	Prof. Herdman.....	Official.
Dec. 26th, 1906, to Jan. 8th, 1907	Dr. H. E. Roaf.....	Digestive ferments of Invertebrates.
March 25th, to April 26th	Mr. H. J. B. Wollaston .....	Plankton Statistics.
March 28th to April 29th	Prof. Herdman .....	Plankton.
April 2nd to April 29th	Mr. R. D. Laurie.....	Biometry and regeneration in Crustacea.
April 2nd to April 11th	Mr. E. J. Whitnall .....	General.
April 4th to April 18th	Mr. E. E. Unwin .....	Photography of marine animals.
April 5th to April 10th	Mr. S. Chaffers.....	Marine Diatoms.
April 6th to April 27th	Mr. W. J. Dakin .....	Anatomy and Physiology of Pecten.

DATE.	NAME.	WORK.
April 11th to April 25th	Mr. W. A. Gunn .....	General.
	Miss E. Bury.....	
	Miss M. Cheetham .....	
	Miss W. Herdman .....	
	Miss E. Hirst.....	
	Miss M. Johnston.....	
	Miss A. Kenyon.....	
April 13th to April 29th	Miss G. Mitchell .....	General.
	Miss D. Moss .....	
	Miss A. Nicholls .....	
	Miss E. Norris .....	
	Miss A. Owen.....	
	Mr. Billington .....	
	Mr. Brown .....	
	Mr. Crook .....	
April 15th to April 17th	Dr. A. T. Masterman .....	Embryology of Solaster.
April 15th to April 29th	Mr. J. Pearson .....	Anatomy and physiology of Cancer pagurus.
April 13th to April 29th	Prof. B. Moore .....	Bio-chemistry of Cancer and Pecten.
April 13th to April 18th	Mr. H. Gunnery .....	Marine Algæ.
May 31st to June 30th	Dr. J. H. O'Connell.....	Actiniaria.
June 14th to July 25th	Mr. F. H. Gravely .....	Embryology of Echinoderma and Polychæta.
June 25th to July 18th	Mr. H. Hawkins .....	Echinoderma.
June 24th to July 5th	Mr. G. A. Dunlop .....	General.
August 1st to August 23rd	Miss Newton .....	Polychæta and Polyzoa.
August 1st to August 23rd	Miss Galloway .....	Polychæta and Polyzoa.
August 3rd to August 24th	Mr. W. Fries .....	Hydroida and Polychæta.

DATE.	NAME.	WORK.
August 9th to Sept. 23rd	Prof. Herdman .....	Plankton.
August 9th to Sept. 26th	Mr. H. J. Buchanan Wollaston.....	Plankton.
August 19th to August 31st	Mr. J. Davidson .....	General.
August 31st to Sept. 21st	Dr. H. E. Roaf .....	Digestive ferments of Invertebrates.
	Miss Herdman .....	

The "Tables" in the Laboratory were occupied as follows:—

*Liverpool University Table :—*

Professor Herdman.	Prof. B. Moore.
Dr. Roaf.	Mr. H. J. Buchanan Wollaston.
Mr. R. D. Laurie.	Miss Herdman.
Mr. W. J. Dakin, B.Sc.	Mr. J. Davidson.
Mr. J. Pearson, M.Sc.	Miss W. Herdman.
Mr. W. A. Gunn.	

*Liverpool Marine Biology Committee Table :—*

Dr. A. T. Masterman.	Mr. E. E. Unwin.
Dr. J. H. O'Connell.	Mr. H. Gunnery.
Mr. W. Fries.	Mr. Dunlop.

*Manchester University Table :—*

Mr. E. J. Whitnall.	Mr. F. H. Gravely.
Mr. S. Chaffers.	Mr. H. Hawkins.

*Birmingham University Table :—*

Miss Newton.	Miss Galloway.
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The following students of Liverpool University occupied the Junior Laboratory, and worked together under the supervision of Professor Herdman, Mr. Pearson and Mr. Laurie:—

Miss E. Bury.	Miss E. Norris.
Miss M. Cheetham.	Miss A. Owen.
Miss E. Hirst.	Miss A. Nicholls.
Miss A. Kenyon.	Mr. Billington.
Miss M. Johnston.	Mr. Brown.
Miss G. Mitchell.	Mr. Crook.
Miss D. Moss.	

In addition, Mr. Robert Okell, F.L.S., Secretary to the Manx Fishery Board, paid frequent official visits to the Biological Station.

The Laboratory was also inspected during the year by Professor Hickson, F.R.S. (Manchester), Mr. Stanley Gardiner (Cambridge), Professors Heincke and Ehrenbaum, of the Heligoland Biological Station; Dr. A. T. Masterman, H.M. Inspector of Fisheries; Mr. J. G. Legge, Director of Education in Liverpool; Dr. J. Travis Jenkins, Superintendent of the Lancashire and Western Sea-Fisheries; and other naturalists and officials.

#### CURATOR'S REPORT.

I take the following paragraphs almost verbatim from the detailed report furnished to me by Mr. H. C. Chadwick:—

“The work of the past year has been characterised by gratifying progress in every department except that of the fish hatchery, where, owing to various causes, the number of plaice larvæ hatched was considerably below that of last year. The number of students who have occupied the laboratories shows a marked increase, and though original researches have not figured quite so largely as last year, much good work has been done. During the Christmas vacation, at Easter, and again in September, Dr. Roaf continued his researches on the digestive ferments of Invertebrates, and upon the secretion of the hypobranchial glands of Mollusca, and, during the latter period, began an inquiry into the physiological condition of what are known to local fishermen as “granny” edible crabs. During the Easter vacation, Professor B. Moore devoted some time to the bio-chemistry of the blood and other tissues of *Pecten*. Mr. Pearson and Mr. Dakin continued their work on the edible crab (*Cancer*) and *Pecten* respectively, and Mr. Laurie instituted some experiments on regeneration of lost parts in the higher Crustacea. On the faunistic



side excellent work was done by Dr. O'Connell, who, in addition to extending our knowledge of the distribution of species of Actiniaria already known, added the name of at least one species to the local fauna. During a stay of over five weeks, Mr. F. H. Gravely devoted much attention to the plankton fauna of the bay, and laid future workers under an obligation by identifying a number of larval forms. Amongst other interesting features of the faunistic work of the year may be mentioned the discovery by Dr. O'Connell and Mr. Gravely of the Lucernarian *Halicystus auricula* at Fleshwick, where large numbers were found adhering to the fronds of the alga *Alaria esculenta* on the North side of the bay. The colour of the Lucernarian so nearly resembled that of the alga that a little practice of the eye was necessary to enable the collector to detect the animals. Dr. O'Connell found several colour varieties of *Corynactis viridis* abundant in the rock pools under Bradda Head, and added *Sagartia rosea* from the Calf Sound to our list of local anemones. To the same list Professor Herdman added *Bunodes thallia* and *Stomphia churchiæ* from a bank about eight miles off Ballaugh, and the beautiful little coral *Paracyathus pteropus*, Gosse, from the Train Bank off Port Erin. All these rare species are now to be seen alive in our Aquarium.

"Tow-nettings have been taken in the bay more frequently throughout this year than for several years past, and much of the time I have been able to spare for shore work has been devoted to the collection of the various marine animals required for research purposes. During the months of August and September, nearly the whole of my time was devoted to the identification and preservation of the specimens dredged by Professor Herdman from his steam-yacht "Ladybird," and to the

supervision of the lobster hatching and rearing carried on in the fish hatchery.

"A few additions have been made to the Library by purchase and exchange, and have added materially to its usefulness."

#### THE AQUARIUM.

"In spite of an exceptionally rainy season, the Aquarium has more than maintained its recognised position amongst the chief attractions of the neighbourhood, over 15,500 visitors having paid for admission. Of this number nearly 10,000 came in July and August, and in the latter month 553 were admitted on one day. Not without some difficulty during the busy months of the spring and late summer the tanks have been maintained in good condition by the Assistant Curator. The only addition to the fishes exhibited therein is the haddock, the exceptional abundance of which in the neighbourhood enabled us to secure a supply. The table tanks now contain a really fine collection of anemones, as regards both individuals and species, including the rarer forms, *Aureliana augusta*, *Sagartia herdmani*, *Bunodes thallia*, and *Stomphia churchiæ*. Over one thousand copies of the "Guide to the Aquarium" have been sold, and the applications for copies I have had from people at a distance show that its usefulness is by no means confined to our own institution."

#### THE FISH HATCHERY.

"Our work in the Fish Hatchery has not been quite so successful this year as last. The hatching season was throughout marked by a high percentage of unfertilised eggs, and the total number spawned was considerably smaller than that of last year. Otherwise the work progressed normally, and 3,460,500 larval plaice were liberated between March 21st and May 10th inclusive,

chiefly from Professor Herdman's steam-yacht "Lady-bird." The majority of the adult fish which furnished the eggs had been retained in the pond from the previous season, and to these 119 were added by means of trammel nets worked by the Assistant Curator in the bay.

"The approximate numbers of the eggs collected and of the young fish set free upon the dates specified are given in the following table:—

Eggs collected.	Date.	Larvæ set free.	Date.
26,000 ...	Feb. 25	19,000 ...	Mar. 21
29,000 ...	" 27	25,000 ...	" 21
18,500 ...	Mar. 1	12,000 ...	" 21
82,000 ...	" 4	68,000 ...	" 26
69,000 ...	" 6	50,000 ...	" 26
76,000 ...	" 7	70,000 ...	" 28
47,000 ...	" 9	42,000 ...	" 28
43,500 ...	" 11	40,000 ...	April 1
83,000 ...	" 12	77,000 ...	" 1
43,000 ...	" 14	32,500 ...	" 1
100,000 ...	" 15	50,000 ...	" 1
111,000 ...	" 19	85,000 ...	" 4
168,000 ...	" 21	140,000 ...	" 8
160,000 ...	" 23	140,000 ...	" 9
229,000 ...	" 25	198,000 ...	" 11
315,000 ...	" 27	211,000 ...	" 13
105,000 ...	" 28	84,000 ...	" 15
395,000 ...	" 30	355,000 ...	" 16
336,000 ...	April 1	281,000 ...	" 19
194,000 ...	" 2	131,000 ...	" 22
304,500 ...	" 4	368,500 ...	23
284,000 ...	" 6		
250,000 ...	" 8	200,000 ...	" 25
231,000 ...	" 9	158,000 ...	" 27
143,000 ...	" 11	120,000 ...	May 4
131,000 ...	" 13	91,000 ...	" 6
138,000 ...	" 15	80,000 ...	" 6
178,500 ...	" 16	123,500 ...	" 6
132,000 ...	" 18	59,000 ...	" 6
79,000 ...	" 20	49,000 ...	" 6
61,000 ...	" 22	46,000 ...	" 6
16,000 ...	" 24	11,000 ...	" 10
84,000 ...	" 25	44,000 ...	" 10
<u>4,662,000</u>		<u>3,460,500</u>	

“The smaller, or western, pond was drained on May 15th, in preparation for further experiments in lobster culture, and we then found between 300 and 400 young plaice which had been hatched on April 25th, 1906, and were thus just over a year old. I carefully measured 300 of these fish, and found the largest to be  $5\frac{3}{8}$  inches in length, and the smallest  $1\frac{7}{8}$  inches, the mean length being  $2\frac{3}{4}$  inches. All these young fish appeared to be in a perfectly healthy condition, and seemed well nourished for their size. They must have subsisted entirely upon the minute floating organisms in the water of the pond. The wide range in size, considering that they were all of exactly the same age, is noteworthy. Several of them afforded excellent examples of bi-colouration, pigment being present on both sides of the body, and only a small portion of the anterior end of the usually unpigmented lower side being normal in colour.”

#### LOBSTER CULTURE.

“During the months of May and June twenty ‘berried’ female lobsters were purchased from the local fishermen and placed in the western pond. Large stones were arranged so as to afford hiding-places for them, and they were regularly fed with pieces of fresh fish. This was done in order to find out whether the conditions were favourable to the retention of the eggs on the swimmerets of the parent lobster until they were ready for hatching. On July 18th the pond was again drained, and it was found that while some of the lobsters had stripped themselves of their eggs, others had retained them, and that the retained eggs were beginning to hatch out. It was also found that the bottom of the pond was covered with a luxuriant growth of a green filamentous alga, and that the eggs of the lobsters were involved in it. As it



appeared probable that the larvæ would also become entangled and eventually perish, I decided on the following day to remove the parent lobsters to the hatching tanks indoors. They were accordingly placed one in each of the middle compartments of the tanks, and hatching boxes were placed in the lowest compartments in order to retain the newly-hatched larvæ. Other boxes were placed in the uppermost compartments in view of rearing the larvæ. Early in August several 'berried' lobsters with nearly-ripe eggs were brought in by fishermen and were added to our stock. I am unable to say with any approach to accuracy how many larvæ were hatched, but 2,550 in the first and second stages, and 80 in the 'lobsterling' stage were set free in the sea as follows:—

Date.		Stage.			No.
July	22nd	...	First	...	500
"	24th	...	First	...	500
"	26th	...	First	...	500
"	29th	...	Second	...	300
August	5th	...	Second	...	350
"	23rd	...	First	...	300
September	2nd	...	Second	...	100
"	2nd	...	Lobsterling	...	7
"	11th	...	"	...	12
"	19th	...	"	...	31
"	25th	...	"	...	20
October	4th	...	"	...	10
Total					<u>2630</u>

A number of the larvæ in the early stages, and all the lobsterlings, were set free inside the ruined landing pier at the base of the breakwater, where there is abundance of shelter from predaceous fishes and where young lobsters are known to occur. Of the remaining young larvæ a number were liberated, from the s.v. 'Ladybird,' along the northern side of the Calf

Island, where the Port Erin fishermen set their traps, and the remainder off Spanish Head, where the Port St. Mary men fish."

Mr. F. H. Gravely, Demonstrator of Zoology in the University of Manchester, who occupied the Work-Table of that University during the greater part of June and July, 1907, has sent me the following note upon some of the observations made in the course of his work.

#### MR. GRAVELY'S REPORT.

"The following finds appear to be worthy of note:—

##### HYDROZOA.

*Syncoryne eximia*.—Only once recorded before, and then from the dredge ("Fauna," Vol. IV., p. 279), and once, I believe, found by Mr. Dakin in water from his laboratory tap at Easter. This summer it occurred in sheets over the vertical and overhanging faces of the blocks on the W. side of the breakwater at and below low water level; it was also obtained from rock pools at Port St. Mary, the Calf Sound (both sides), and in the little bay by the caves just round the angle of the cliffs by the Castle Rocks. Mr. Chadwick has since found it in quantity covering the cork floats attached to a number of crab-pots.

*Garveia nutans*.—No published record from the Isle of Man as yet, I think. I found this in a deep rock pool above low-water mark on the Port Erin side of the Calf Sound.

*Tubularia indivisa* var. *obliqua*.—This form occurred on an overhanging ledge of rock just above low water mark at Port St. Mary. It is characterised by a single large (0.2 × 0.1 mm.) tentacle covering the umbrella-mouth of each female gonophore and capable of moving

to some slight extent. A similar form from Hammerfest has been described by K. Bonnevie under the name of *T. obliqua* (Zeitschr. wiss. Zool.; Jahrg. 63; 1898 "Zur Systematik der Hydroiden") and figured amongst the Hydroida of the Norske Nordhavs-Expedition, 1896-8; Christiania, 1899. This new species was founded for a single specimen, which Fröken Bonnevie tells me was a female. G. Swenander has since found similar gonophores produced by colonies, many of the zooids of which bore the normal non-tentaculate gonophores of *T. indivisa* (Det Kongl. Norske Vid. Selsk. Skr. 1903; Trondhjem, 1904; No. 6. "Über die Athecaten Hydroiden des Drontheimsfjordes"). He therefore regards Bonnevie's species as a variety of *T. indivisa*.

None of the female specimens from this rock at Port St. Mary that I have examined have failed to show the presence of the tentacle on most of the gonophores, though in one case at least it is absent from a few of them; and in addition to this it is unusual for their blastostyles to be long and pendulous as is usual in *T. indivisa*. Pendulous female blastostyles have occasionally been seen, however, and occurred in Bonnevie's original specimen; they are a constant feature of the male hydranth. There are also certain minor differences to be seen between sections of the gonophores of this form and of the normal *T. indivisa*. The female shows a single radial canal instead of four—a feature obviously correlated with the presence of the single large tentacle to the base of which the canal runs, there communicating with the large endodermal cavity of the tentacle; whilst the male shows no radial canals (or tentacles) at all, but does show—what the normal *T. indivisa* apparently does not—conspicuous sterile cells in the outer layers of sperm, these cells often bearing delicate processes that pass inwards towards the spadix,

as has been described in male gonophores of *T. hodgsoni* (Hickson and Gravely: Hydroid Zoophytes of the National Antarctic Expedition; Brit. Mus. 1907, p. 14, Pl. iv., fig. 34).

In spite, however, of these well-marked differences of anatomy occurring in the one or two specimens of each sex thus carefully examined (and so probably also in the others), as well as of the presence of the large tentacle on the female gonophores, it seems to me, in view of Swenander's statements, to be better to regard Bonnevie's *T. obliqua*, and so also the Port St. Mary specimens, as a variety of *T. indivisa* at any rate until further information is obtained as to the weight to be given to these characters. It would be at least inconvenient to be unable to determine the species of one sex without the examination of carefully prepared sections.

*Obelia longissima*, which has up to the present apparently only been recorded from the L.M.B.C. area at Little Ormes Head and Blackpool ("Fauna," Vol. I., p. 102), was found in large quantities by Mr. Dunlop on the lower parts of the lines attached to lobster-pots between Port Erin and Fleshwick Bay. Although the colonies resembled *O. longissima* as defined by Hincks in the great depth of the hydrothecae and the straightness of the stem, they resembled *O. flabellata* in the dentate margins of the hydrothecae and the subverticillate appearance of the colony due to the forking of the branches at their bases. It is interesting in this connection to note that colonies of *O. flabellata* dredged near the Isle of Man in 1885 ("Fauna," Vol. I., p. 103) were in a very similar way intermediate between the species to which they were referred and *O. dichotoma*. *Halecium tenellum*, which I gather from the "Fauna,"



Vol. III., p. 49, has previously only been obtained by dredging, was found in rockpools on Bradda Head.

#### POLYCHAETA.

The following new Polychaeta were obtained:—

*Syllis* sp. (? young *monilaris*, Sav.), among the rocks below the Biological Station.

*Pionosyllis lamelligera* (de Saint-Joseph), dredged near Bay Fine.

*Pionosyllis* sp., from the breakwater.

*Odontosyllis ctenostoma* (Clpd.), and another species of this genus, which I have not been able to identify, were to be found swimming at the surface of the sea outside the bay on very calm evenings.

*Autolytus incertus* (Mgr.), and four other species of the sexual generation of this genus, were taken in the tow-net at the surface; one (additional ?) species was dredged near Bay Fine, several sexual individuals being attached to the asexual stock in this case; neither of the species of *Autolytus* mentioned in the 1898 list was taken.

*Myrianida pinnigera* (Mont.)—A fine specimen bearing about a score of sexual (♀) individuals was found under a stone, at extreme low water, on the shore below the harbour-master's house.

#### NUDIBRANCHIATA.

I did not pay much special attention to these, but see that the following which I identified from Alder and Hancock's monograph are not in the British Association list, though I believe that Mr. Chadwick is aware of the presence of all of them at Port Erin:—

*Doris pusilla*, dredged off Bay Fine.

*Doris depressa*, Port Erin side of the Calf Sound; identification a little uncertain, as the specimen escaped before reaching the Biological Station.

*Doris repanda*, Port Erin Bay at low water; differs from Alder and Hancock's description in that it has no conspicuous yellow patches; possibly also the arrangement of the gills is not quite normal.

*Eolis despecta*, on *Obelia longissima* from lobster-pot lines North of Port Erin Bay.

#### ECHINODERMATA.

The commonest *Ophiopluteus* larva found at Port Erin during this period was one not yet identified with its mature form, and so still referred to as *Ophiopluteus mancus* in "Nordisches Plankton."

Plutei of *Ophiothrix fragilis* were rather less common, those of *Ophioglypha albida* still rarer, and those of *Ophioglypha texturata* (= *Ophiura ciliaris*) were very rare.

*Echinocardium cordatum*; very common.

*Echinus esculentus*; common.

*Echinus miliaris*; common.

*Echinocyamus pusillus*; not common.

Asterid larvae taken were:—

*Asterias rubens*;

"*Brachiolaria laevis*."

Holothurian larvae were:—

*Synapta digitata*.

#### ENTEROPNEUSTA.

Tornaria larva of *Balanoglossus* was fairly abundant.

The most striking features of the summer, however, were the extraordinary luxuriance of the Hydroid fauna almost everywhere—*Syncoryne eximia* occurring in such sheets on the breakwater that it seems impossible to believe that it could have been overlooked there before had it been as luxuriant regularly, and the large number and size of the gonophores on *Coryne pusilla* may be noted

as striking examples of this; the unusual abundance of *Tornaria* larvae and of *Halicyclustus*—the latter at Fleshwick especially, where it was first discovered this year by Dr. O'Connell; and the change in the character of the bottom off Bay Fine, which perhaps may account for the discovery there of a curious little orange-coloured Coelenterate attached to the concave surface of empty mussel shells, and believed by Dr. O'Connell to be young *Cerianthus*.

The following Hydroids, collected at Hilbre Island on the occasion of the joint Liverpool and Manchester Biological Societies' excursion, on May 29th, 1907, are not recorded from that locality in Miss Thornely's table on pp. 225-228 of the "Fauna," Vol. IV.

*Bimeria vestita* is to be found on the stems of *Tubularia indivisa*.

*Campanularia flexuosa* must, I think, have been overlooked in drawing up the list, as it is extremely common under ledges of rock."

#### MR. SCOTT'S REPORT.

Mr. Andrew Scott, A.L.S., has sent me his usual "Faunistic Note" containing additions to our knowledge of the crustacean life of our district, as follows:—

"A few additions to the fauna of the Irish Sea have turned up since the last Annual Report and are recorded below. These all belong to the Crustacea, and are representatives of the Schizopoda, Sympoda or Cumacea, and Copepoda. The worker who studies the Crustacea from that portion of the Irish Sea which has been investigated so long by the Liverpool Marine Biology Committee, appears to have little to hope for in the way of new species or even new records of known species. It is very creditable to those investigators of the past, who, with

limited appliances and often working under most adverse conditions at sea, were able to do so much good work. Any new records that one obtains are due entirely to the more systematic and exhaustive investigations carried on now, which were impossible in the past. A good deal yet remains to be done, however, before the various organisms inhabiting the sea round the Isle of Man are completely known. The deep channel between the Isle of Man and Ireland is still practically virgin ground. The few hauls snatched from it by a stroke of luck have revealed interesting forms. Under the International Investigations, the deep water of the Farøe Channel is now shown to have a rich and varied crustacean life; while we know from the monographs of Professor G. O. Sars and numerous papers by other workers that the deep water of the Norwegian Fjords has a rich fauna. The beautiful copepod *Euchæta barbata*, Brady, described from a single specimen taken off the East coast of S. America during the "Challenger" investigations, is not uncommon in those northern depths. Turning to our own shores we find, from the investigations of Sir John Murray, the Fishery Board for Scotland, the Fisheries Branch of the Department of Agriculture and Technical Instruction for Ireland, &c., that the deep waters of the Scottish lochs, e.g., Loch Fyne, and off the west coast of Ireland have a fauna quite distinct from the shallower regions, at any rate as regards the crustacea. It is rather remarkable that we should know so much concerning the animals inhabiting the deep waters mentioned, and yet know practically nothing about the life in the deep water, of over 50 fathoms, between England and Ireland. This deep area forms a nearly continuous portion of the sea bottom from the Atlantic, North and South of Ireland. A narrow strip of this



channel, measuring nearly 30 miles long by about two miles wide, is over 100 fathoms deep. The greatest depth given on the Admiralty Chart is 149 fathoms, and is traversed by the telegraph cable between Portpatrick and Donaghadee. An investigation of this area beyond the 50 fathom line can only be attempted with a good sea-going vessel, well furnished with scientific apparatus. This has not been available in the past, but would be possible with the aid of an annual grant from the Government, on the lines suggested by Professor Herdman in the Report on the Lancashire Sea-Fisheries Laboratory for 1906.

The additions now recorded were mostly obtained from Professor Herdman's collections of plankton taken off the Isle of Man during the Easter and summer vacations of 1907, from the yacht "Ladybird." Two of them are from collections outside the 50 fathom line.

*Erythropus erythropthalmus* (Göes). Three specimens of this schizopod were found in a collection taken with the "shear" net between Calf Island and Port Erin on April 18th, 1907.

*Eudorella emarginata* (Kroyer). This cumacean, easily recognised by the large semilunar emargination at the anterior edges of the carapace, and the very prominent tooth-like process defining the ventral limit of the emargination, was found in two collections made with the Hensen net on August 24th, 1907. The samples were from the deep area and contained much fine mud.

*Microcalanus pusillus*, G. O. Sars. Professor Sars describes this little copepod in his great work on the Crustacea of Norway. It is said to be a true deep-water form and only occurred in depths of more than 150 fathoms. The species was not uncommon in hauls made with the Hensen and Nansen nets at depths between 50

fathoms and 60 fathoms, on August 24th, 1907. It is very small, about 0.7 mm. in length, and is easily overlooked.

*Ameira intermedia*, T. Scott.—Four specimens of this little copepod were found in a Hensen net collection from Wart Bank, on August 29th.

*Heteropsyllus curticaudatus*, T. Scott.—One or two specimens of this curious form were taken in a Hensen net collection near Piel Gas Buoy in the course of one of the monthly investigations at present being conducted between Piel and Ormes Head (January, 1907).

*Chondracanthus zeii*, De la Roche.—Specimens of this peculiar parasitic copepod have been found on the gills of *Zeus faber* captured from time to time in the trawl of the "John Fell," during the present year. The species is evidently not a common one. On October 8th seven specimens of Dory, captured near Puffin Island, were examined, and only one *C. zeii* was found. *Caligus zeii* on the other hand was present on the skin of all the fish.

*Lernæa lusci*, Bassett-Smith.—One specimen on the gills of *Gadus luscus* captured off Morecambe Bay Light-vessel by the fisheries steamer, February, 1907."

#### FURTHER NOTES ON WORK.

Dr. H. E. Roaf continued, on several occasions during the year, his investigation of the digestive processes of lower animals. Extracts were made from the digestive glands of various Invertebrata, and the action of these extracts in digesting different kinds of food material is now being examined in detail in the physiological laboratory of the University.

Dr. Roaf has also been investigating at Port Erin the bio-chemistry of the hypobranchial gland (or glands) of Mollusca, and has shown that the mantle of the dog-

whelk, *Purpura lapillus*, contains a substance which in its chemical properties and physiological action is allied to the active substance obtained from the supra-renal bodies of Vertebrates. This secretion was at first supposed to be derived from the "purple" gland, but microscopic examination and re-actions seem to show that the active substance is obtained from a glandular tract lying alongside the purple gland (see paper by H. E. Roaf and M. Nierenstein in Proc. Physiol. Soc., June 22nd, 1907, Journ. Physiol., Vol. 36).

Mr. Lomas has commenced a renewed examination of the mineralogical constituents in the samples of bottom-deposits that we bring up in the dredge from different banks, and the results of his work will be given in a future report.

Mr. Douglas Laurie has started an investigation of Dimorphism in male spider-crabs, but this has not yet gone far enough to give any results.

As *Paracyathus pteropus*, which we dredged this summer from the Train bank, 8 miles off Port Erin, is a distinctly rare British coral, it may be useful to print here the following brief description drawn up by Mr. Chadwick from the animal now living in our aquarium:—

*Column*—cylindrical, not much higher than the corallum.

*Disk*—flat, or very slightly raised in the centre; no distinct margin.

*Tentacles*—twenty-eight in number, arranged in two alternating circlets; stem gradually tapering, membranous, translucent, studded with numerous warts (?cnidophores); head sub-globular, opaque.

*Mouth*—a lengthened and very mobile slit, with crenulate lips.

*Colour*—column, disk and tentacles transparent white; a broad vandyked band of vivid emerald green surrounding the mouth.

*Diameter of corallum*—3 mm.

This coral was described by Gosse (*Actinol. Brit.*, p. 321) from a specimen found attached to a shell of *Cyprina* from the deepest part of the Moray Firth. The soft parts of the animal were unknown to Gosse, so the above description may be useful.

#### “GRANNY” CRABS.

The term “Granny” is used by the Port Erin fishermen in connection with certain crabs which they consider to be unhealthy and useless, but which, curiously enough, are not necessarily either old or female. These crabs are caught in considerable abundance during July and August, in the pots set along the northern shore of the Calf Island, but are rarely, if ever, brought home by the men. They are recognised as inedible and unsaleable, and when caught are promptly killed and thrown into the sea. The “granny” crab, which may be of any size above four inches, generally female, is recognised by its worn and dilapidated appearance, the shell being pitted and stained with black, and the great claws corroded and frequently broken. The surface is frequently overgrown with barnacles and other foreign bodies. The men say that if a crab in this condition is eaten the flesh will be found to have a strong bitter taste, and a powerful purgative effect medicinally. No one who knows will willingly taste them, the merchants will not buy them, and the impression amongst the fishermen is that they are diseased and permanently useless and that possibly they may infect others, and consequently the “grannies” are invariably killed on sight.



We feel confident, however, that there is nothing abnormal about these crabs and that they are merely individuals which are approaching the time when in every second year, a crab this size will cast its shell. Mr. Pearson, in his forthcoming memoir on the Crab, will discuss this question and show that this is the most probable conclusion to arrive at. In this case these crabs, if left alive in the sea, would probably cast their shells in the course of a few weeks, and would then become, after passing through a period as "soft" crabs, normal clean-looking, healthy individuals, suitable for the market. The bitterness of the flesh of the "granny" and its medicinal effect still require explanation, and Dr. H. E. Roaf is now investigating these matters as a question of bio-chemistry; but it may be pointed out that the period of preparation for casting the shell is probably one of active change in the metabolism of the body, and may well give rise to changes in the secretions sufficient to account for the observed facts.

If, then, the "grannies" are natural crabs passing through a transitory phase in their life-history it is evident that they should, when captured, be restored to the sea uninjured, and that much damage may be done to the local fisheries by the present practice of destroying such crabs. Every "granny" returned alive to the sea this year may be caught as a healthy crab a size larger next year.

#### INTENSIVE STUDY OF PORT ERIN BAY.

This is no new subject, but I desire to attract renewed attention to it in the hope of inducing the co-operation amongst observers which is essential for its successful pursuit.

At the very first meetings of the Committee in 1885 the intensive study of small areas was put forward as one of our aims, and Hilbre Island was then chosen as the locality to be systematically and minutely examined and recorded. Some progress was made, specimens were collected and observations recorded; but in a very few years, for what seemed then to be very good and sufficient reasons, the scene of our work was shifted to Puffin Island, and again after a period of years to Port Erin. In each case, and in each successive year, records were kept and some advance was made; but other objects which seemed at the moment more pressing, if not ultimately more important, such as sea-fisheries investigations, students' classes, and the preparation of L.M.B.C. Memoirs, from time to time intervened. Still the object was always kept in view, and occasional contributions to it were made. In the fourteenth of these Annual Reports (1900) I discussed some aspects of the matter under the headings "Distributional Charts" (p. 23), and "A 'Census' of the Sea," (p. 26). We had then recorded over 2,000 species of marine animals from Port Erin, and in that report six distributional charts were published giving some information as to the occurrence of these animals. This was a beginning of such a detailed biological survey of our district as we have often put before us as one of our primary objects. Much, however, remains to be done, and it is work that ought to be undertaken by many observers, who will divide up the groups and the localities between them. I hope to induce students and others working at the station during the coming year to co-operate with us, and I re-print here the plan of Port Erin Bay (fig. 3), which was drawn up seven years ago, in the expectation that the squares into



which the area was then divided may prove useful to observers in fixing localities. The exact distribution of even the commonest species, the relative abundance in different habitats, and at the same place in different years, the presence of varieties in some localities and not in others, and the comparison of large numbers of individuals from exposed and from sheltered, from shallow and from deep, from clear and from turbid waters, are amongst the problems or lines of work included in the intensive study of a small area.

The next two sections of this report, on the Plankton Investigations and on the Comparison of three Fishing Banks off the Isle of Man, are both of them further examples of intensive study of small areas which have been carried on during the last year, and will be continued. But in addition to these, which can only be conducted at sea, from a steamer, I desire especially to direct renewed attention of all workers at Port Erin to the necessity of taking up again with energy, and in co-operation, that systematic survey of the bay which we started in 1900.

#### PLANKTON INVESTIGATIONS AT PORT ERIN.

It will be remembered that in last year's Report I published the results of observations made the previous summer off Port Erin, which tended to confirm the belief that the plankton (minute suspended organisms in the sea) has no such regularity and uniformity in distribution as is sometimes supposed. The importance of the matter lies in this—that if there is not this perfect uniformity over wide areas we must not attempt to draw general conclusions from comparatively few and distant observations. We must learn the meaning and relative values of our samples by the intensive study of small



areas, such as the neighbourhood of Port Erin, before embarking on wider oceans.

Convinced of the fundamental importance of such an intensive study, I have spent my three last vacations, the summer of 1906, Easter, 1907, and the summer of 1907 in experimenting day after day with various plankton nets under similar and under varying conditions in a limited sea-area off Port Erin, with results that are startling in their diversity. It was obvious that at all these times the plankton was unequally distributed over the depths, the localities and the dates.

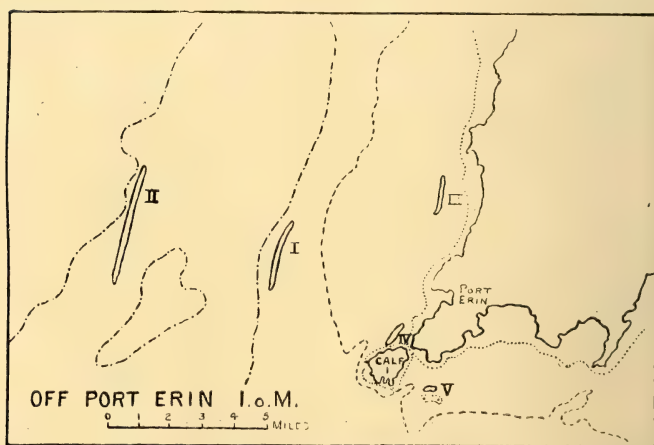


FIG. 4.—Plankton Stations off Port Erin.

The results obtained in the summer of 1906 amounted to 80 gatherings, taken in 40 days, and these were described in our last Annual Report and recorded in more detail by Mr. A. Scott in the Sea-Fisheries Laboratory Report for 1906.

With the view of testing the methods further at another time of year, I devoted a month this spring (March 28th to April 27th) to a systematic exploration,\*

\* I have used some of these results in a Presidential Address to the Linnean Society on May 25th, 1907, and also laid them in abstract before Section D at the British Association Meeting at Leicester; but I print them here because of their local bearing.

from the s.v. "Ladybird," of the sea immediately around the south-west corner of the Isle of Man. The region in which we worked measured (see map, fig. 4) ten miles from east to west (out to sea) and rather less from north to south (along the coast), but the area investigated was really much more limited than these numbers indicate, since the samples were taken from only two "off-shore" stations, one five



FIG. 5.—Petersen-Hensen net going down open.



FIG. 6.—Petersen-Hensen net coming up closed.

miles and the other ten miles out from Bradda Head; and from three "alongshore" stations, one to the north towards Niarbyl, one to the south towards the Calf Island, and one in the "southern sea" off Spanish Head—all in water of much the same depth, about 20 fathoms,

Whilst I was taking these samples in the open sea, almost daily, from the yacht, Mr. Douglas Laurie, with a crew of students from the Biological Station, simultaneously took similar samples inside Port Erin Bay in comparatively sheltered water. In 23 working days I find that we took in all 276 samples, an average of 12 per day. It will be readily understood by anyone who has carried on such work continuously, with varied weather, that it was a busy time; and that on some days we were fairly wet, without any time to get cold, from morning till night. So much practical work could only be carried on with the willing help of several assistants. All on board the yacht helped in various ways, but I must thank especially Mr. Buchanan-Wollaston who assisted me in working the nets, Mr. Chadwick who preserved most of the material in the laboratory at the end of each day's work, and Mr. Andrew Scott, A.L.S., who has systematically examined the samples for me. A detailed account of these gatherings will appear elsewhere; I propose at present to discuss only some of the more obvious features of the series—partly from my own records made at the time of collection and partly from Mr. Scott's notes.

At each station, after taking the bearings and the depth, we first lowered two vertical nets (see figs. 5, 6, 7 and 8, from photos taken by Mr. R. Okell), the Petersen-Hensen and the Nansen, to a depth of 20 fathoms, pulled them up slowly through 10 fathoms, and then closed them by "messengers" run down the line. This gave us samples, taken vertically with these two very different nets, of the organisms present in the water between 10 and 20 fathoms. After that three ordinary horizontal open tow-nets exactly alike in all respects (size, shape, mesh, age) were put over—one (A) with a weight attached was allowed to sink to a depth of about 10 fathoms, from

which it gradually rose as the ship went slowly ahead; while the other two (B and C), unweighted, remained continuously at or just under the surface and worked side by side like a pair of sharks or porpoises swimming in our wake. These two last nets ought, if there is any uniformity whatever in the plankton even in the most limited areas, to give similar results, and of course they did so in most cases. My purpose in taking the two similar surface nettings side by side was to show this, and also to test the reliability of the sample; for I would only consider it a trustworthy sample when these two nets agreed in their evidence. Where, under the circumstances stated above, the gatherings differed notably, there must have been some accident in the working of the nets or some abnormality in the distribution of the plankton, such as, no doubt, will sometimes be encountered when traversing the edge of a swarm of gregarious organisms; and it is important to get some evidence as to how frequently such accidents or abnormalities may be met with. For example, on April 2nd, at Station III., I find that the two surface-nets used together gave 17 c.c. and 42.5 c.c. of material respectively; on April 9th, at Station I., 2.5 and 8 c.c. respectively; and on April 24th, at Station II., they gave 7 c.c. and 15 c.c. respectively. On most occasions, of course, they were very similar and on some almost identical in their catch.

The net A (which may be called the weight-net) is of use as having traversed a wider range, 0 to 10 fathoms, so as to sample all the water above the zone traversed by the vertical nets, and it frequently, and in fact usually, obtained a larger gathering and showed a greater variety of organisms than either the deeper, closing (vertical), or the open surface nets.



On some occasions, at the "along-shore" stations (e.g., 2 miles off Bradda Head) hauls were taken with a new "shear-net" made on the principle of the Heligoland "Scherbrutnetz" (*Conseil International—Rapports et Procès-verb.*, vol. ii. p. 62, 1904). This was used as a mid-water net—being lowered to a depth of 5 to 10 fathoms, where, through the action of the shearing plate, placed like a vertical otter-board, it remained even when the ship went ahead at a moderate speed, and so formed

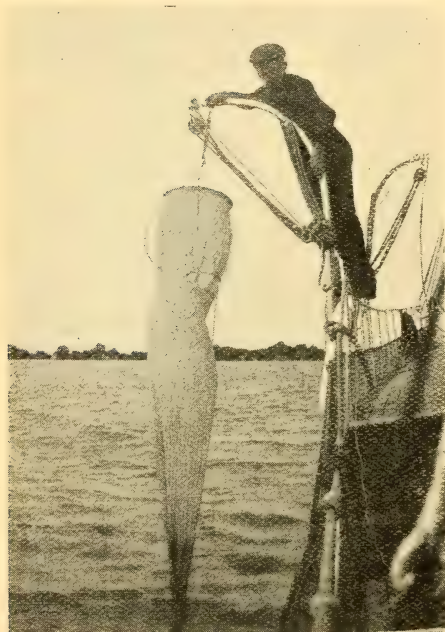


FIG. 7.—Nansen net going down open.



FIG. 8.—Nansen net coming up closed.

a most efficient instrument of capture in waters where the ordinary net cannot be towed. The mouth measured nine feet in circumference, the net was over 10 feet in length, and being formed of rather coarse mesh caught large

quantities of the larger organisms of the plankton such as *Sagitta*, *Medusæ*, *Ctenophora*, *Zoëas*, the larger *Copepoda* and some young fishes.

As a vertical closing net I greatly prefer the Nansen (figs. 7 and 8) to the Petersen-Hensen (figs. 5 and 6). It is lighter and less complicated (a matter of some importance in a rough sea), more easily manipulated, less liable to failure in action, costs less and catches more for its size of opening. The brass cylinder at the lower end is, however, too small, and might be improved in other ways.

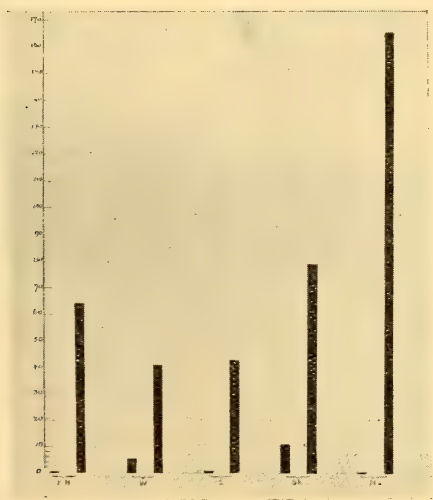


FIG. 9.—Showing by proportional columns the range in quantity taken by the various Plankton nets in April, 1907.

The localities to be sampled, all within a ten-mile radius of Port Erin, were—the two “off-shore” stations, No. I. five miles and No. II. 10 miles from Bradda Head respectively, and three “along-shore” stations, No. III.

towards Niarbyl, No. IV. towards the Calf Island, and No. V. off Spanish Head (fig. 4). The nets to be compared were:—two vertical deep-water, the Nansen and the Petersen-Hensen, and three horizontal, one weighted and the other two surface. In addition a shear-net gathering was taken on occasions from intermediate waters. Each haul of the horizontal nets was a 15 minutes one.

I give here (p. 68) in tabular form, my first statement of results, which may require to be modified in detail or supplemented later on, but which may be taken as substantially correct. Whether one looks at the hauls with the same net at the one locality on different days, or at neighbouring localities on the same day, the want of uniformity both in quantity and in quality is striking. The range for all nets is from 0·5 c.c. to 164 c.c., and the same for the Nansen; for the Petersen-Hensen it is from 0·5 to 64·5 c.c., for the weighted open net from 5·5 to 41 c.c., for the surface nets from 1 c.c. to 42·5 c.c., and for the shear-net from 11 to 78·5 c.c. The diagram (fig. 9) shows graphically the proportions between these hauls.

One or two broad features of the collection are obvious. In the earlier part of the time, up to about the middle of April, Diatoms were abundant, and nearly all the gatherings had a greenish tinge. During that period the plants were more abundant in the bottom waters, and the animals at the surface.

Day after day we found that the two closing vertical nets hauled up from 20 to 10 fathoms were of a brownish-green colour and contained (especially the Nansen) an abundant gathering of Diatoms. The surface nets during this time contained more Copepoda. On April 15th and 19th, however, when the change in plankton was taking place the Diatoms are found to be mainly on the surface and the Copepoda below. As an example of wide distri-

bution I may cite April 10th, when the nets gave consistent results all the afternoon at three localities north of Port Erin, the Diatoms being in all cases more abundant at the bottom and the Copepoda on the surface.

We were fortunate enough on one occasion to obtain incontrovertible evidence of the sharply defined nature of a shoal of organisms, forming an instructive example of how nets hauled under similar circumstances a short distance apart may give very different results. On the evening of April 1st, at the "alongshore" Station III., north of Port Erin, off the "Cronk" one mile out, I took six simultaneous gatherings in both surface and deeper waters. Two of the nets were the exactly similar surface tow-nets which I have called B and C. At half-time, as the result of a sudden thought I hauled in B, emptied the contents into a jar, and promptly put the net out again. This half gathering was of very ordinary character, containing a few Copepoda, some Diatoms and some larvæ, but *no Crab Zoëas*. At the end of the 15 minutes, when all the nets were hauled on board, all the gatherings, including B, showed an extraordinary number of Crab Zoëas rendering the ends of the nets quite dark in colour. B was practically the same as C although B had only been fishing for seven minutes. It was evident that at about half-time the nets had encountered a remarkable swarm of organisms which had multiplied several times the bulk of the catch and had introduced a new animal in enormous numbers. Had it not been for the chance observation of the contents of B at half-time, it would naturally have been supposed that, as all the nets agreed in their evidence, the catches were fair samples of what the water contained over at least the area traversed—whereas we now know that the Zoëas were confined to at most the latter half of the traverse and may







have been even more restricted. Under these circumstances, an observation made solely in the water traversed during the first seven minutes would have given a very different result from that actually obtained; or, to put it another way, had two expeditions taken samples that evening at what might well be considered as the same station, but a few hundred yards apart, they might have arrived at very different conclusions as to the constitution of the plankton in that part of the ocean.

We have a good deal of evidence as to the distribution of the organisms in horizontal zones; and, when Diatoms are not present in great quantity, the most prolific zone off Port Erin seems to be from 5 to 10 fathoms below the surface.

As an example of a case where two similar nets hauled side by side gave very nearly the same amount of material, but where the kinds and numbers of organisms present in the catch when examined were found to be very different, I give the following lists of the contents\* of the two surface nets after a 15-minutes' haul on April 13th, 1907, at Station III. The one net contained 16 c.c. and the other 15·5 c.c., but these amounts were made up very differently in the two cases. For example, it will be seen that in the net C there were no *Balanus Nauplei* and no immature Copepoda, while thousands of both were present in B. Then, again, in B there were very few adult *Temora*, while in C practically all the *Temora* were adult. The lists will show other points of difference. I may add that in the haul of the shear-net, taken at the same place and time, there were 1,380 larvæ of *Pectinaria* in tubes, along with 5,400 *Balanus Nauplei*, and many other organisms.

---

\* Only omitting those organisms where less than ten individuals were obtained.

	Net B = 16 c.cm.	Net C = 15.5 c.m.
Larval Polychaeta ...	650	0
Balanus Nauplei ...	3,000	0
„ Cypris stage ...	50	0
Copepoda Nauplei ...	7,000	2,000
„ juv. ...	13,000	0
Calanus helgolandicus ...	100	6
Pseudocalanus elongatus ...	850	500
Temora longicornis ...	2,470	4,750
Oithona similis ...	100	50
Acartia clausi ...	250	200
Centropages hamatus ...	0	200
Coscinodiscus concinnus ...	8,000	14,000
Biddulphia mobiliensis ...	40,000	70,000
Rhizosolenia semispina ...	1,000	3,000
Lauderia borealis ...	1,000	0
Thalassiosira nordenskioldii ...	2,000	7,000
„ subtilis ...	6,000	0
Chætoceros teres ...	0	1,000
Peridinium sp. ...	500	0
Plutei ...	500	1,000
Oikopleura sp. ...	2,000	150
Medusoids ...	50	25
Sagitta bipunctata ...	0	48
Crab Zoëas ...	0	10

This shows very clearly that the two gatherings, although alike in quantity, were unlike in quality.

As a sample of the manner in which, as the result of Mr. Scott's work, we are now recording these plankton hauls, I give here the following table dealing with one of the off-shore stations on a forenoon run in the "Ladybird." The shear-net haul was taken on the way in, half-way between the Calf Island and Port Erin.



Net used .....	I.	II.	Hensen.	Nansen.	Weight.	Shear.
Depth in fathoms .....	0	0	—	—	—	—
Catch in c.cm. ....	23·5	17·5	5·5	9·5	17·5	275
Biddulphia mobiliensis .....	750	2,250	500	250	2,500	1,000
Chætoceros contortum .....	—	250	36,000	63,000	500	250
„ debile .....	—	—	—	2,000	—	—
„ decipiens .....	—	—	2,500	4,000	—	—
„ sociale .....	—	—	1,500	2,000	—	—
Coscinodiscus concinnus.....	1,750	2,750	200	250	1,000	200
Ditylium brightwellii .....	—	—	500	—	—	—
Eucampia zodiacus .....	—	—	1,000	—	—	—
Lauderia borealis .....	—	—	5,000	14,000	—	500
Rhizosolenia shrubsolei ...	250	250	2,000	2,000	500	—
Thalassiosira gravida .....	—	—	500	1,000	—	—
„ nordenskiöldii .....	2,000	4,500	65,000	134,000	8,500	500
Rhizosolenia stolterfohti ...	—	—	1,000	2,000	—	—
Leptocylindricus danicus ...	—	—	4,000	3,000	250	—
Ceratium furca .....	—	—	1,000	500	—	—
„ fusus .....	250	250	—	500	1,500	—
„ tripos .....	500	750	—	—	1,000	—
Peridinium .....	—	2,250	500	6,000	750	—
Acanthometra .....	—	—	—	100	50	—
Medusoid gonophores .....	200	250	10	120	300	1,800
Plutei of Echinoderms .....	200	200	—	—	—	—
Sagitta bipunctata .....	12	—	1	6	27	123
Autolytus prolifer .....	—	—	—	—	—	1
Larval Polychæta .....	60	50	—	20	20	250
Mitraria .....	400	250	—	—	500	—
Crab zoea .....	20	—	—	—	8	16
Mysis stage of Crangon ...	2	—	2	10	37	72
First stage Nephrops .....	—	—	—	4	4	11
Podon intermedium .....	150	150	—	—	—	—
Evadne nordmanni.....	100	100	—	—	150	50
Calanus helgolandicus .....	1,600	600	10	120	1,200	850
Pseudocalanus elongatus ...	200	150	100	770	1,600	500
Temora longicornis .....	300	200	30	150	2,300	750
Centropages hamatus .....	100	100	—	—	—	50
Anomalocera pattersoni ...	500	400	5	—	—	—
Acartia clausi .....	2,600	2,400	40	125	1,600	50
Oithona similis .....	400	300	5	50	150	—
Copepod nauplii .....	250	4,500	4,000	—	7,000	250
„ Juv. ....	2,000	3,000	100	18,000	4,000	150
Barnacle nauplii .....	30	25	10	75	75	650
„ cypris stage .....	2	—	1	—	—	6
Oikopleura sp. ....	3,300	2,750	140	500	3,300	750
Fish eggs, Rockling .....	6	1	—	—	—	9
Common Dragonet .....	10	2	—	—	4	7
Topknot .....	1	3	—	—	—	—
Bib .....	9	8	1	1	2	5
Whiting .....	13	12	—	—	11	3
Cod .....	8	1	—	—	—	1
Green Cod .....	1	3	—	2	2	4
Haddock .....	1	4	—	—	—	—
Gurnard .....	—	1	—	—	2	—
Dab .....	—	5	—	—	—	—
Sprat .....	—	1	—	—	—	2
Spotted dragonet .....	—	—	—	—	—	1
Young fishes, Gadoid .....	—	—	1	1	2	10
„ Clupeoids .....	—	—	—	—	—	10

During the recent summer vacation (August 9th to September 20th, 1907) with the assistance of Mr. Buchanan-Wollaston and others, I again worked the plankton nets on every possible opportunity from the s.v. "Ladybird," trying to make a still more intensive study of a limited district. On this occasion over 300 gatherings were taken in 30 days, an average of 10 per day. On one trip (September 20th) 36 gatherings were taken in an afternoon, in a small area of only about two miles extent, as follows:—

LOCALITY A:—6 miles out, W.N.W. of Bradda, over 30 fms.

- |    |                                    |                       |  |
|----|------------------------------------|-----------------------|--|
| 1. | Hensen and Nansen nets let down to | 30 fms. and hauled up | 10 fms. (30-20).                       |
| 2. | " "                                | " "                   | 20 fms. " " 10 fms. (20-10).           |
| 3. | " "                                | " "                   | 10 fms. " " 10 fms. (10-0).            |
| 4. | " "                                | " "                   | 30 fms. " " { open to surface } (30-0) |

Weighted open net (A) and two surface nets (A1 and A2) along with shear net (Sh, 1) at 15-20 fms.

Weighted open net (B) and two surface nets (B1 and B2) along with shear net (Sh. 2) at 7.8 fms.

(These each  $\frac{1}{4}$ -hour hauls; the one set taken immediately after the other.)

Mill water bottle at 20 fms., strained at the time.

“ “ at 20 fms., strained on shore.

LOCALITY B:—8 miles out W.N.W. of Bradda, over 30 fms.

- |    |                                    |                       |                                |
|----|------------------------------------|-----------------------|--------------------------------|
| 1. | Hensen and Nansen nets let down to | 30 fms. and hauled up | 10 fms. (30-20).               |
| 2. | " "                                | " "                   | 20 fms. " " 10 fms. (20-10).   |
| 3. | " "                                | " "                   | 10 fms. " " 10 fms. (10-0)     |
| 4. | Nansen (alone)                     | " "                   | 30 fms. " " to surface (30-0). |

Weighted open net (C) and 2 surface nets (C1 and C 2) along with shear net (B1) at 7-8 fms.

Weighted open net (D) and 2 surface nets (D1 and D2) along with shear net (B2) at 15-20 fms.

(These each  $\frac{1}{4}$ -hour hauls; the one set taken immediately after the other.)

Mill water bottle at 20 fms., at 10 fms., and at 5 fms.

The object I had in view on most occasions was to sample the various layers of water, as well as to compare neighbouring localities and adjoining dates, and the following diagrammatic statement of certain of the hauls taken on September 12th will illustrate the plan of work adopted to differentiate the zones:—

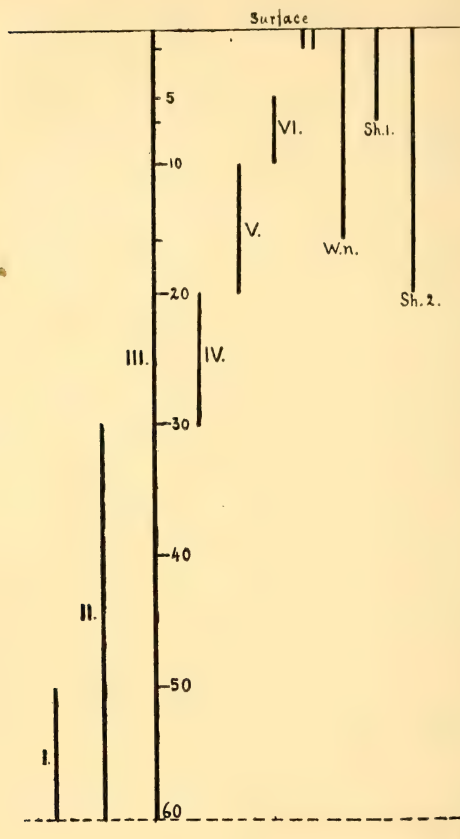


FIG. 10.—Diagram to show the hauls taken at one station. I.—VI. represent hauls of the vertical closing nets; W.n. (weight net), Sh. 1 and Sh. 2 (shear net) and the two surface nets represent horizontal or oblique hauls. The numbers 5 to 60 indicate depths in fathoms.

Here, out in the middle of the Channel between Ireland and the Isle of Man, the depth was about 65 fathoms, and we sank our vertical nets down to 60, and hauled them up through the lower 10 fathoms (I.), the lower 30 (II.), and the entire depth (III.), then through the zones 30 to 20 (IV.), 20 to 10, and 10 to 5.

That brought us in touch with the surface zone through which the weight-net, the shear-nets, and the surface-nets had ranged. In this way we hope to be able to localise the constituents of the fauna obtained in a vertical haul such as III.

The full details of the results obtained from these 300 hauls taken in summer, as well as of the 276 taken at Easter and the 80 of the previous summer, will be given in a paper by Mr. Scott and myself, which we hope to have ready for the Annual Report of the Lancashire Sea-Fisheries Laboratory early in 1908; but in the meantime it may be of interest to readers if I give here one more list showing the results of a haul on Station V. inside the Wart bank (see fig. 4). One remarkable feature of this occasion was that the Hensen net hauled up from 14 fathoms contained 150 specimens of what is considered by Mr. Scott to be a new species of *Leptopsyllus*, while the Nansen net used at the same time, and at the same depth, on the other side of the ship, caught twice as much material but not a single specimen of the new Copepod. The surface nets (I. and II.) are also somewhat divergent in their results.

Net used .....	I.	II.	Hen.	Nan.	Weight.
Depth in fathoms .....	0	0	—	—	—
Catch in c.cm. ....	4.5	3	.3	.7	30
<hr/>					
<i>Biddulphia mobiliensis</i> .....	700	750	20	50	1,000
<i>Chætoceros contortum</i> .....	—	—	15	10	—
„ <i>decepiens</i> .....	—	—	15	—	—
<i>Coscinodiscus radiatus</i> .....	—	—	10	—	—
„ <i>concinus</i> .....	—	200	—	—	—
<i>Rhizosolenia semispina</i> .....	250	1,000	25	10	—
<i>Ceratium fusus</i> .....	—	500	10	10	500
„ <i>tripos</i> .....	250	2,750	70	20	1,000
<i>Peridinium</i> .....	250	300	5	—	—
<i>Trochiscia brachiolata</i> .....	—	200	10	25	250
<i>Sagitta bipunctata</i> .....	27	21	—	1	125
<i>Tomopteris onisciformis</i> .....	—	1	—	—	—
Larval <i>Polychæta</i> .....	200	—	40	—	—
' <i>Mitraria</i> ' .....	75	—	—	—	—
Crab zoea .....	—	—	—	—	2
„ <i>megalo</i> .....	1	—	—	—	—



Mysis stage of Crangon .....	5	3	—	3	36
Podon intermedium .....	10	—	—	—	15
Calanus helgolandicus .....	34	7	—	—	67
Pseudocalanus elongatus ...	4,500	830	100	325	23,000
Temora longicornis .....	200	25	8	10	700
Centropages hamatus .....	150	25	5	10	200
Acartia clausi .....	1,255	150	8	100	6,000
Oithona similis .....	4,500	3,250	35	15	6,500
Paracalanus parvus .....	200	150	4	6	—
Isias clavipes .....	—	25	—	—	300
Leptosyllus sp. ....	—	—	150	—	—
Ameira intermedia .....	—	—	4	—	—
Zaus goodsiri .....	—	—	—	—	2
Copepod nauplii .....	17,000	22,500	340	2,450	38,000
„ Juv. ....	15,000	750	40	600	19,000
Gasteropods, larval .....	250	200	20	50	500
Lamellibranchs, larval .....	250	500	20	50	500
Oikopleura sp. ....	875	900	25	10	—
Ascidian eggs .....	1,500	1,500	—	—	2,000
Young fishes .....	—	—	—	—	6

## COMPARISON OF THREE FISHING BANKS.

In the “Annals and Magazine” for 1839 Professor Edward Forbes published a short paper entitled, “On a shell-bank in the Irish Sea, considered Zoologically and Geologically” (Ann. and Mag. Nat. Hist., Vol. IV., 1840, p. 217), in which he recorded the results obtained during some years of occasional dredging on a scallop bank lying opposite Ballaugh off the North-West of the Isle of Man. As these observations extended over seven years previous to 1839, if we reckon from a period about the middle of his work we may consider that we are now dealing with a record of the condition of the marine fauna on this bank well over 70 years ago. It seemed to me that we had here an opportunity, such as rarely occurs, of determining whether any change had taken place in a limited, well-defined area after a considerable interval of time. Forbes, unfortunately, did not deal with all groups of animals, and in fact he paid most attention to Mollusca, and only recorded in addition the Echinodermata and a few of the



FIG. 11.—Map of the Isle of Man. Ballaugh lies a little inland half-way between Kirkmichael and Jurby Head.

Zoophytes. Still we may be thankful for what he has given us at such an early date, and it will be interesting to see what can be made of it in comparison with our

observations at the present time. He ends his paper with the following paragraph:—

“I have drawn up these observations chiefly in the hope of inducing others to present us with similar reviews of the shell-banks of our coast. Geology and zoology will gain as much by inquiring how our marine animals are associated together as by investigating genera and species, though the former subject has, as yet, been but little attended to in comparison with the latter.”

That sentiment is in thorough accord with the views of nature expressed in these L.M.B.C. reports, and it is in the same spirit that we now examine, and hope to add to Forbes' observations of seventy years ago; we are only continuing, and I hope extending, the work that he began so well.

As yet we have had only a few days' work on the Ballaugh bank, and if we have already found more species than Forbes records, that does not necessarily lead us to the conclusion that the fauna is now more abundant, since we have dealt with some groups of animals that were not given in the older list, and possibly our modern methods with a convenient steamer, an Agassiz-trawl and wire-rope enable us to work more rapidly and effectively. But looking merely at the groups recorded by Forbes we find that we have not found quite so many Mollusca, but a great many more Zoophytes and Polyzoa. The bank seems to be particularly rich in Nudibranchiata and in Cœlenterata; in one haul we counted 200 beautiful colonies of *Alcyonium digitatum*, including both white and orange forms.

There is no object in making a detailed comparison or attempting to draw any conclusions until we have done more work on the bank, and accumulated a greater number of records. It occurred to me, however, that it would be interesting to extend the range of the observations by

including two other shell-banks under slightly different conditions, and showing apparently very different bottom-deposits. These are (1) the Train bank, lying about 8 miles N.W. of Port Erin, where there is a good deal of mud mixed with the sand; and (2) the Wart bank, lying 2 miles S. of Spanish Head, near Port St. Mary, and having the bottom formed chiefly of broken shells and other calcareous



FIG. 12.—Showing the Agassiz-trawl being swung in on the derrick.

fragments. These three banks—the Ballaugh, the Train, and the Wart—lying in the “Coralline” zone off the Isle of Man, ought, in the end, to give us interesting information in regard to the common characteristics and the individual features of such fishing banks in our seas.



The work will be gone on with whenever opportunity offers, and we shall hope to return to the subject in a future report.

### L.M.B.C. MEMOIRS.

During this year two important Memoirs have been added to our published series, and two additional ones of still larger size are now nearly completed. No. XIV. on *LIGIA*, the large shore Isopod Crustacean, by Mr. C. Gordon Hewitt was issued in January, and Mr. Chadwick's Memoir on *ANTEDON*, the

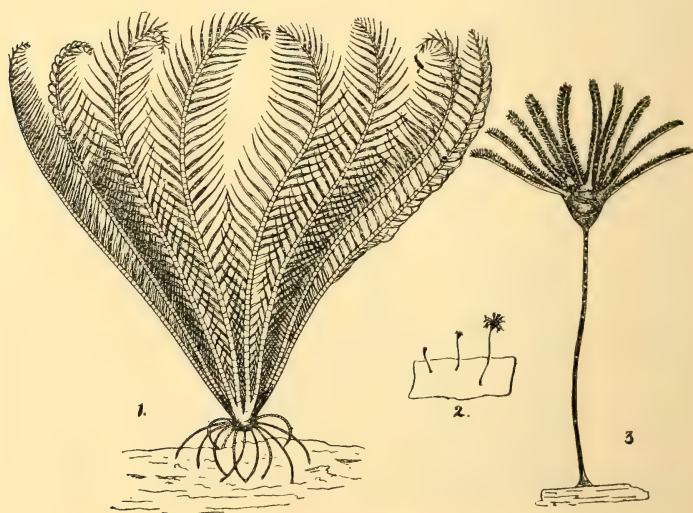


FIG. 13.—*Antedon bifida*, the rosy feather-star:  
1. Adult, nat. size; 2. stalked larva, nat. size; 3. larva magnified.

Rosy-Feather-Star (fig. 13), illustrated by seven beautiful plates, appeared in June. Mr. Dakin's *PECTEN*, the Scallop, is now in my hands and will probably be out in December or January; and Mr. Pearson's *CANCER* (the edible crab) will follow soon after as our seventeenth

Memoir. Still others are in active preparation. We frequently receive, from heads of laboratories, suggestions of types that it would be useful to get undertaken, and, from naturalists, of Memoirs that they are willing to write. As I remarked last year this unusual amount of excellent material which the Committee is happy to be able to issue to the scientific world, is, however, embarrassing from the point of view of expense. Lithographic plates, such as these memoirs require, seem to become more costly, and with the growing elaboration of the subject more detailed illustration is necessary. The Committee are therefore very grateful to those friends who have kindly by special donations enabled the Treasurer to meet the expenses of plates for several of the above-mentioned Memoirs. Further donations towards the illustrations of those still unpublished will be very welcome.

The following shows a list of the Memoirs already published or arranged for:—

- Memoir I. ASCIDIA, W. A. Herdman, 60 pp., 5 Pls., 2s.  
 „ II. CARDIUM, J. Johnstone, 92 pp., 7 Pls., 2s. 6d.  
 „ III. ECHINUS, H. C. Chadwick, 36 pp., 5 Pls., 2s.  
 „ IV. CODIUM, R. J. H. Gibson and Helen Auld,  
 26 pp., 3 Pls., 1s 6d.  
 „ V. ALCYONIUM, S. J. Hickson, 30 pp., 3 Pls.,  
 1s. 6d.  
 „ VI. LEPEOPHTHEIRUS AND LERNÆA, Andrew  
 Scott, 62 pp., 5 Pls., 2s.  
 „ VII. LINEUS, R. C. Punnett, 40 pp., 4 Pls., 2s.  
 „ VIII. PLAICE, F. J. Cole and J. Johnstone, 260 pp.,  
 11 Pls., 7s.  
 „ IX. CHONDRUS, O. V. Darbishire, 50 pp., 7 Pls.,  
 2s. 6d.  
 „ X. PATELLA, J. R. A. Davis and H. J. Fleure,  
 84 pp., 4 Pls., 2s. 6d.

Memoir XI. ARENICOLA, J. H. Ashworth, 126 pp., 8 Pls.,  
4s. 6d.

„ XII. GAMMARUS, M. Cussans, 55 pp., 4 Pls., 2s.

„ XIII. ANURIDA, A. D. Imms, 107 pp., 8 Pls., 4s. 6d.

„ XIV. LIGIA, C. G. Hewitt, 45 pp., 4 Pls., 2s.

„ XV. ANTEDON, H. C. Chadwick, 55 pp., 7 Pls.,  
2s. 6d.

PECTEN, W. J. Dakin.

CANCER, J. Pearson.

DORIS, Sir Charles Eliot.

OYSTER, W. A. Herdman and J. T. Jenkins.

CUCUMARIA, E. Hindle.

OSTRACOD (CYTHERE), Andrew Scott.

BUCCINUM, W. B. Randles.

BUGULA, Laura R. Thornely.

ZOSTERA, R. J. Harvey Gibson.

HIMANTHALIA, F. J. Lewis.

FUCUS, J. B. Farmer.

BOTRYLLOIDES, W. A. Herdman.

CUTTLE-FISH (ELEDONE), W. E. Hoyle.

ACTINIA, J. A. Clubb.

HALICHONDRIA and SYCON, A. Dendy.

HYDROID, E. T. Browne.

PERIDINIAN, C. A. Kofoid.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Pagurus*, *Sagitta*, *Pontobdella*, a Cestode and a Pycnogonid.

We append to this Report:—

- (A) The usual Statement as to the constitution of the  
L.M.B.C., and the Laboratory Regulations;
- (B) The Hon. Treasurer's Report, List of Subscribers,  
and Balance Sheet.

APPENDIX A.

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THE LIVERPOOL MARINE BIOLOGY  
COMMITTEE (1907).

HIS EXCELLENCY THE RIGHT HON. LORD RAGLAN, Lieut.-Governor of the Isle of Man.

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PROF. W. A. HERDMAN, D.Sc., F.R.S., P.L.S., Liverpool,  
Chairman of the L.M.B.C., and Hon. Director of the  
Biological Station.

DR. W. E. HOYLE, M.A., University, Manchester.

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MR. A. LEICESTER, Liverpool.

SIR CHARLES PETRIE, Liverpool.

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MR. ARNOLD T. WATSON, F.L.S., Sheffield.

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Curator of the Station—MR. H. C. CHADWICK.

Assistant—MR. T. N. CREGEEN.

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## CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The OBJECT of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.



II.—The COMMITTEE shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the AFFAIRS of the Committee shall be conducted by an HON. DIRECTOR, who shall be Chairman of the Committee, and an HON. TREASURER, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any VACANCIES on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting, of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The EXPENSES of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The BIOLOGICAL STATION shall be used primarily for the Exploring work of the Committee, and the SPECIMENS collected shall, so far as is necessary, be placed in the first instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

## LIVERPOOL MARINE BIOLOGICAL STATION

AT

PORT ERIN.

---

LABORATORY REGULATIONS.

I.—This Biological Station is under the control of the Liverpool Marine Biological Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are:—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges.

Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

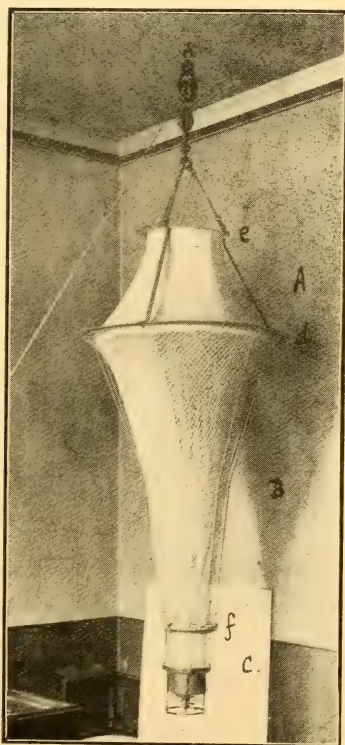
VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at

the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.



Hensen's Plankton Net.



## APPENDIX B.

## HON. TREASURER'S STATEMENT.

The list of Subscribers and Balance Sheet for 1907 is herewith appended. The latter shows a small balance due to the Treasurer, which indicates the necessity there is for additional support, as expenses during the past few years have necessarily increased now that the work of the Port Erin Biological Station has been so materially enlarged.

The L.M.B.C. Memoirs have proved of the greatest service, both to the senior students in University Laboratories and to investigators in Biological Stations. They have been much appreciated by scientific men, both in this country and America, and are very favourably reviewed in *Nature* and other papers. These Memoirs are illustrated by lithographic plates, and are necessarily expensive to produce, and, as they are sold at a very low price, the receipts as yet do not cover the cost of production.

During the past year, Memoirs No. XIV., "*Ligia*" (a Shore Crustacean), and No. XV., "*Antedon*" (the Rosy-Feather-Star), were published, and the MSS. for several more are in preparation, two, in fact, being already completed and ready to print.

Welcome donations of £30 from Mrs. Holt and Miss Holt, and £20 from Mr. T. Sutton Timmis, have just been received towards the plates of the forthcoming Memoirs on "*Pecten*" (the scallop), and "*Cancer*" (the edible crab).

Further Memoirs will be published as funds permit, and the Treasurer will gladly receive donations for this purpose, or for the necessary working expenses of the Biological Station at Port Erin.

EDWIN THOMPSON,

Hon. Treasurer.

1, Croxteth Grove,

Liverpool, December, 1907.

## SUBSCRIBERS.

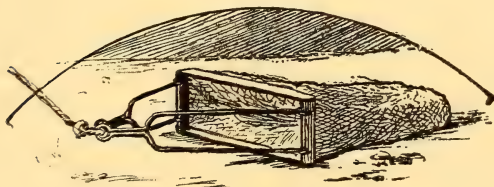
	£	s.	d.
Beaumont, W. I., Citadel Hill, Plymouth ...	1	1	0
Bickersteth, Dr., 2, Rodney-street... ..	2	2	0
Briscoe, F. W., Colby, Isle of Man ... ..	1	1	0
Brown, Prof. J. Campbell, University, Liverpool..	1	1	0
Browne, Edward T., B.A., 141, Uxbridge- road, Shepherd's Bush, London ... ..	1	1	0
Boyce, Sir Rubert, F.R.S., University, Liverpool	1	1	0
Brunner, Mond & Co., Northwich... ..	1	1	0
Brunner, Sir J. T., Bart., M.P., Liverpool ...	5	0	0
Brunner, J. F. L., M.P., London ... ..	2	2	0
Caton, Dr., 78, Rodney-street, Liverpool ...	1	1	0
Clubb, J. A., Public Museums, Liverpool... ..	0	10	6
Cowley, R. C., Laurel Bank, Garston ... ..	0	10	6
Crellin, John C., J.P., Andreas, I. of Man... ..	0	10	6
Crosfield, Harold G., Fulwood-park, Liverpool ...	1	1	0
Dale, Vice-Chancellor, University, Liverpool ...	1	1	0
Davis, Prof. Ainsworth, University College, Aberystwyth ... ..	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescott ...	2	2	0
Eliot, Sir Charles, University, Sheffield ... ..	1	1	0
Gair, H. W., Smithdown-road, Wavertree ...	2	2	0
Gaskell, Holbrook, J.P., Woolton Wood ... ..	1	1	0
Gossage, the late F. H., Camp Hill, Woolton ...	5	0	0
Halls, W. J., 35, Lord-street, Liverpool ... ..	1	1	0
Headley, F. W., Haileybury College, Hertford ...	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hewitt, David B., J.P., Northwich ... ..	1	1	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Holland, Walter, Carnatic Hall, Mossley Hill ...	2	2	0
Holt, Alfred, Crofton, Aigburth ... ..	2	2	0
Holt, Alfred, Junr., Crofton, Aigburth ... ..	1	0	0
Forward ... ..	£44	1	6

	£	s.	d.
Forward ... ..	44	1	6
Holt, Mrs., Sudley, Mossley Hill ... ..	2	2	0
Holt, P. H., Croxteth-gate, Sefton-park ... ..	1	1	0
Holt, R. D., 54, Ullet-road, Liverpool ... ..	2	0	0
Hoyle, Dr. W. E., Museum, Owens College ... ..	1	1	0
Isle of Man Natural History Society ... ..	1	1	0
Jarmay, Gustav, Hartford, Cheshire ... ..	1	1	0
Jones, Charles W., J.P., Allerton Beeches ... ..	1	0	0
Lea, Rev. T. Simcox ... ..	1	1	0
Leicester, Alfred, 30, Brunswick-street, Liverpool	1	1	0
Lewis, Dr. W. B., W. Riding Asylum, Wakefield...	1	0	0
Manchester Microscopical Society... ..	1	1	0
Meade-King, R. R., 4, Oldhall-street ... ..	0	10	0
Monks, F. W., Warrington... ..	2	2	0
Muspratt, E. K., Seaforth Hall ... ..	5	0	0
Narramore, W., Cambridge Avenue, Gt. Crosby...	1	1	0
O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool ... ..	1	1	0
Okell, R., B.A., F.L.S., Sutton, Douglas, I. of Man	1	1	0
Petrie, Sir Charles, Devonshire-road ... ..	1	1	0
Pilkington, J. A., Bank House, Maghull ... ..	1	1	0
Quayle, Alfred, 7, Scarisbrick New-road, Southport	1	1	0
Rae, Edward, Courthill, Birkenhead ... ..	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... ..	1	1	0
Rathbone, Miss May, Northumberland-street, London ... ..	1	1	0
Rathbone, Mrs., Green Bank, Allerton ... ..	2	2	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	0
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Simpson, J. Hope, Ivy lodge, Aigburth ... ..	0	10	6
Smith, A. T., 43, Castle-street ... ..	1	1	0
Sorby, Dr. H. C., F.R.S., Broomfield, Sheffield ...	1	1	0
Forward ... ..	£81	7	0

	£	s.	d.
Forward...	81	7	0
Tate, Sir W. H., Woolton, Liverpool ...	2	2	0
Thompson & Capper, 4, Lord-street, Liverpool ...	1	1	0
Thornely, Miss, Nunclose, Grassendale ...	0	10	0
Thornely, Miss L. R., Nunclose, Grassendale ...	2	2	0
Timmis, T. Sutton, Cleveley, Allerton ...	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool ...	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Walker, Horace, South Lodge, Princes-park ...	1	1	0
Watson, A. T., Tapton-crescent, Sheffield...	1	1	0
Whitley, E., Clovelly, Sefton-park, Liverpool ...	2	2	0
Weiss, Prof. F. E., Owens College, Manchester ...	1	1	0
Wiglesworth, Dr., Rainhill... ..	1	1	0
Wragg, Sir W., D.C.L., Port St. Mary, Isle of Man	1	1	0
Wright, C. H., 9, Cook-street, Liverpool ...	1	1	0
	<u>£101</u>	<u>16</u>	<u>0</u>

## SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

Victoria University, Manchester ... ..	£10	0	0
University, Liverpool ... ..	10	0	0
University, Birmingham ... ..	10	0	0
	<u>£30</u>	<u>0</u>	<u>0</u>



The Naturalist's Dredge.



## THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr.

IN ACCOUNT WITH EDWIN THOMPSON, HON. TREASURER.

Cr.

1907.

To Balance due Treasurer, December 20th, 1906...	£	s.	d.
" Printing and Stationery :—	1	10	9
" Printing Memoirs .....	13	15	9
" Plates for Antedon Memoir .....	31	3	0
" Printing Report for 1906 .....	16	13	1
" Illustrations for 1907 Report .....	2	4	2
" Boat Hire .....	2	14	3
" Books and Apparatus at Port Erin Biological Station .....	17	0	1
" Postage, Carriage, &c. ....	11	8	10
" Natural History Specimens .....	3	19	9
" Salary, Curator .....	75	0	0
" " Assistant .....	27	6	0
" Sundries .....	10	0	5
	£212	16	1

EDWIN THOMPSON,

HON. TREASURER.

LIVERPOOL, December 20th, 1907.

1907.

By Subscriptions and Donations received .....	£	s.	d.
" Amount received from Universities for hire of " Work Tables " .....	92	10	0
" Dividend, British Workman's Public House Co., Ltd., Shares .....	30	0	0
" Sale of Nat. Hist. Specimens .....	4	19	0
" Interest on British Association (1896) Fund ..	2	2	2
" Bank Interest .....	38	0	0
" Laboratory and Class Fees .....	0	15	2
" Sale of Guides, &c. ....	3	0	0
" Sale of Bottles, &c. ....	12	10	9
" Admissions to Aquarium .....	1	3	9
" Sale of Memoirs .....	13	9	0
" Balance due to Treasurer .....	8	10	3
	0	16	0
	£212	16	1
Endowment Invested Fund :—			
British Workman's Public House Co.'s shares .....	£173	1	0
Memoir Fund—Balance in Bank .....	£14	6	0
" " Donation from Mrs. and Miss Holt... 30 0 0	30	0	0
" " " " T. Sutton Timmis, Esq. 20 0 0	20	0	0
	£64	6	0

Audited and found correct,

COOK &amp; LEATHER,

Chartered Accountants.

REPORT on the INVESTIGATIONS carried on during 1907 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at the University of Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. ANDREW SCOTT, A.L.S., Resident Fisheries Assistant at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries Assistant at the Liverpool Laboratory.

(With plates and text figures.)

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## INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

On account of my mission to the Ceylon pearl banks in February and March, this Report does not appear this year until a few weeks later than the usual date. There are, however, advantages in the slight delay, since it has enabled one or two of the sections to be more thoroughly worked up. Moreover, as this report deals with the completed work up to the end of 1907, it really, in going to press in April, is appearing in very good time compared with the usual practice of most Annual Reports.

## WORK AT PIEL.

There is comparatively little that need be said about the work at the Piel laboratory and hatchery. Mr. Scott's section of the report (see below) will show that he has successfully hatched and turned out into the sea about thirteen and a half millions of young flat fish. He reports to me that the spawning fish he now has are in satisfactory condition and that the prospects for the present season are good.

The fishermen's classes were held at the Piel Laboratory in the usual manner and with the usual success. One of the results of the continued success of these classes, and of our natural desire to hold as many of them as is possible in the season, is that our two scientific assistants, Mr. Johnstone and Mr. Scott, are occupied in this work during that period of the year when the principal food-fishes are spawning, when the eggs are appearing in our surface nets and other changes are taking place in the floating life of the sea. I feel that it is a distinct loss to us that these naturalists are prevented at that important part of the year from taking almost daily observations from the steamer. When we get, as I hope we soon shall, an increase in our investigating staff it will be very important to have one naturalist at least on the steamer constantly, engaged in carrying on investigations and in recording observations daily.

Mr. Scott contributes a section of this report on the results of the Hensen net hauls undertaken in the eastern portion of the Irish Sea between Barrow and North Wales. These results are interesting not only for comparison amongst themselves, station with station and period with period throughout the year, but also because

of the considerable differences that they present to the hauls made with the Hensen, Nansen and other forms of net off Port Erin and elsewhere round the South end of the Isle of Man.

As Mr. Scott points out, we have during this last year collected and examined more than twice as many gatherings as in any previous year. The Plankton discussed in last year's report amounted to 400 samples; this year it has run up to nearly 900. The increase is, however, due not so much to work in the Lancashire district as to the very large number of samples which I took with various kinds of experimental nets from the S.Y. "Ladybird" during the spring, summer and autumn of the past year. The results of these experimental hauls are recorded on 126 sheets, many containing records of from five to ten hauls each. The total number of hauls by means of which we have sampled in this manner the water round the South end of the Isle of Man amounts to about 650. This large series has enabled Mr. Scott and myself to discuss the succession of organisms in the Plankton throughout the year in a limited area, and also the distribution, and relative numbers at different times and places, in a manner which had not been previously possible to us. This is only the beginning of such an intensive study of small areas as will be necessary before we can arrive at any correct estimate of the value and representative nature of such samples.

Mr. Buchanan-Wollaston, who has been carrying on fishery work in the University Laboratories, under a grant from the Board of Agriculture and Fisheries, contributes a couple of short papers to this report as the result of his examination of the statistics we have accumulated during the last fifteen years. Although these statistics seem, at first sight, to be large in quantity,



on examination it is found that so many gaps occur in the series that they are not so complete and not so valuable for scientific purposes as might have been expected. It is very unfortunate when a series of observations is deprived of much of its value through some monthly observations having been omitted on account of the steamer being called off to other duties. Every endeavour ought to be made, now that we are starting work with a new, more powerful and more scientifically-equipped vessel, to carry out the periodic observations with punctuality in order that the statistics acquired may be of the greatest possible value—not merely for our own immediate purposes but also for the benefit of future fishery administrators.

Dr. H. Bassett, of our University Chemical Department, has most kindly for the last couple of years undertaken the physico-chemical work in connection with the examination of the samples of sea water obtained on the periodic hydrographic cruises, and he now contributes to this report a paper on his results which is of very great interest; and shows that this work ought certainly to be continued and extended.

Mr. Johnstone has been engaged during the year in his usual important work on the bacteriological examination of the shell-fish beds of the district, but is not yet prepared to report further on the matter. He has also been engaged in working up the results of the marked fish experiments, and has continued to devote attention to the parasites of fishes in the district, and we have from him in this report articles on these two latter questions, to which I need not allude further.

I have pleasure in appending to the report this year a comprehensive memoir on *Cancer*—the Edible Crab, written by Mr. Joseph Pearson, M.Sc. of the Zoological

Department of the University. Mr. Pearson has been working on this Memoir for several years, part of the expenses of his material being met by a grant from the Board of Agriculture and Fisheries, and part of the expense of producing the beautiful plates which illustrate the structure and life-history of the Crab being met by a grant from the fund for research, placed at the disposal of the University by H.M. Treasury, while the remainder of the cost of the plates will be defrayed by the Liverpool Marine Biology Committee. Mr. Pearson has discussed his subject from practically every point of view and has produced an account of the Crab which will, I hope, be regarded as the authoritative work on this important food-animal, and will, I am sure, be a credit to our report and to the Sea Fisheries Committee under whose auspices it is produced.

W. A. HERDMAN.

FISHERIES LABORATORY,  
UNIVERSITY OF LIVERPOOL,  
*February 5, 1908.*

## SEA-FISH HATCHING AT PIEL.

BY ANDREW SCOTT.

The results of the hatching work in the spring of 1907 are very similar to those obtained in the previous year. The adult plaice were brought from Luce Bay by the Fisheries steamer and the flounders from the Barrow Channel by the cutter belonging to the northern division of the district.

The plaice and flounders commenced to spawn on March 2nd, and the first fertilised eggs were secured two days later. The spawning period lasted for two months, and during that period one million four hundred thousand plaice eggs were collected and thirteen million eight hundred thousand flounder eggs. The eggs were incubated in the usual way in the Dannevig apparatus and the resulting fry liberated in the sea. The parent fish were afterwards set free in the Barrow Channel. Towards the end of the year the local fishermen again reported the capture of unusually large plaice from the channel. It is proposed during the present year to find out whether the adult plaice liberated at the end of the hatching season remain in the channel and are eventually captured or entirely leave the neighbourhood. Before being set free a number of the stronger plaice will be marked with the brass label and button as in an ordinary migration investigation, and no doubt the local fishermen will be glad to assist by returning any marked fish that they capture.

The following tables give the number of eggs collected, and of the fry hatched and set free on the dates specified :—

PLAICE (*Pleuronectes platessa*, Linn.).

Eggs Collected.			Fry Set Free.		
March	4	... 12,000	10,000	...	March 30
"	6	... 20,000	17,500	...	" "
"	8	.. 20,000	17,500	...	April 6
"	11	... 40,000	35,000	...	" "
"	14	... 45,000	40,000	...	" 13
"	18	... 65,000	57,500	...	" "
"	20	... 65,000	57,500	...	" 20
"	22	... 75,000	65,500	...	" "
"	26	... 90,000	79,500	...	" "
"	29	... 90,000	79,500	...	" 27
April	1	... 95,000	84,500	...	" "
"	3	... 95,000	84,500	...	" "
"	5	... 95,000	84,500	...	May 4
"	8	... 90,000	79,500	...	" "
"	11	... 85,000	75,000	...	" 11
"	15	... 85,000	75,000	...	" "
"	17	... 80,000	70,000	...	" "
"	19	... 70,000	62,000	...	" 18
"	22	... 60,000	52,500	...	" "
"	24	... 50,000	40,000	...	" "
"	26	... 30,000	26,500	...	" 22
"	29	... 25,000	22,000	...	" "
May	1	... 18,000	15,500	...	" "
Total Eggs		<u>1,400,000</u>	<u>1,231,000</u>	Total Fry	



FLOUNDER (*Pleuronectes flesus*, Linn.).

Eggs Collected.				Fry Set Free.			
March	4	...	150,000	133,000	...	March	30
"	6	...	200,000	177,000	...	"	"
"	8	...	300,000	266,000	...	"	"
"	12	...	400,000	355,500	...	April	6
"	14	...	600,000	532,000	...	"	"
"	18	...	600,000	532,000	...	"	"
"	20	...	700,000	622,000	...	"	13
"	22	...	800,000	712,000	...	"	"
"	26	...	800,000	712,000	...	"	"
"	29	...	950,000	846,500	...	"	20
April	1	...	1,000,000	887,000	...	"	"
"	3	...	1,000,000	887,000	...	"	"
"	5	...	900,000	800,000	...	"	27
"	8	...	800,000	712,000	...	"	"
"	11	...	800,000	712,000	...	May	4
"	15	...	800,000	712,000	...	"	"
"	17	...	600,000	532,000	...	"	"
"	19	...	600,000	532,000	...	"	11
"	22	...	500,000	445,000	...	"	"
"	24	...	500,000	445,000	...	"	"
"	26	...	200,000	177,500	...	"	18
"	29	...	200,000	177,500	...	"	"
May	1	...	150,000	133,000	...	"	22
"	3	...	150,000	133,000	...	"	"
"	5	...	100,000	89,000	...	"	"
Total Eggs 13,800,000				12,262,000	Total Fry.		

Total Number of Eggs    ...    ...    15,200,000

Total Number of Fry    ...    ...    13,493,000

## CLASSES, VISITORS, &amp;c., AT PIEL.

BY ANDREW SCOTT.

Following the system that has now been in operation for several years, the Education Committee of the Lancashire County Council renewed the grant which enabled forty-five bona-fide fishermen residing in the Administrative County of Lancaster to attend a course of instruction at Piel in 1907. The Blackpool Education Committee again sent three men, and the Cheshire Education Committee six men from Hoylake. The studentship holders were divided into four classes, three of fifteen each and one of nine men, as shown by the following lists:—

First Class, held February 25th to March 9th.—John Randles, Hoylake; Sydney Beck, Hoylake; Thomas Nicholson, Hoylake; J. Bird, Hoylake; William Smith, Hoylake; R. Jones, Hoylake; Daniel Cross, Askam-in-Furness; A. Woodhouse, Morecambe; M. Woodhouse, Morecambe; R. Baxter, Morecambe; N. Sumner, Fleetwood; W. Cartmell, Fleetwood; R. Gornall, Fleetwood; H. Johnson, Banks; T. Leadbetter, Banks.

Second Class, held March 11th to 22nd.—G. Thompson, Roosebeck; T. Stephenson, Flookburgh; H. Townley, Morecambe; J. Raby, Morecambe; A. Woodhouse, Morecambe; S. Butler, Fleetwood; J. Abram, Fleetwood; W. Leadbetter, Fleetwood; W. Wade, Fleetwood; W. Hardman, Lytham; A. Anderson, Lytham; E. Rimmer, St. Annes; W. Harrison, St. Annes; Stephen Johnson, Banks; A. Abram, Banks.

Third Class, held April 8th to 19th.—Edward Martin, Baycliff; Thomas Thompson, Baycliff; Albert Hill, Flookburgh; William Benson, Flookburgh; Albert Threlfall, Morecambe; John Houghton, Morecambe;

John Woodhouse, Morecambe; Robert Bell, Morecambe; James Butler, Glasson Dock; John Hardie, Fleetwood; James McMillan, Fleetwood; Joseph Price, Fleetwood; Ernest Railton, Fleetwood; John Abram, Banks; Geoffrey Wareing, Banks.

Fourth Class, held April 22nd to May 3rd.—David Rawlinson, Roosebeck; James Burrow, Bolton-le-Sands; W. Lawrence Fawcett, Morecambe; John Burrow, jun., Heysham; William Hargreaves, Knott End, Fleetwood; John Bridge, Banks; Thomas Melling, Blackpool; Ezekiel Salthouse, Blackpool; Henry Smith, Blackpool.

The usual votes of thanks to the Sea Fisheries Committee and to the Education Committee were proposed and carried by the fishermen.

Two classes in nature study for school teachers were held during the months of April and May. The classes were organised by the Barrow Education Committee and were attended by teachers belonging to their schools. The course of instruction for school teachers has, on the suggestion of Mr. A. Haveridge, Director of Education at Barrow, been somewhat modified and re-arranged. The course has been divided into three stages. The first deals with the common organisms of the sea shore between tide marks, and the general animal and plant remains from the sea bottom washed up along high-water mark. A brief account of their distribution, habits, and uses is given, and an explanation of the methods of collecting, preserving, and mounting natural history specimens for school museums. In the second stage certain common types of marine animals are studied more fully than in the first course. These types include a common fish like the codling or herring, starfishes and sea urchins, common shore crabs, cockle, mussel, &c. The third stage deals with microscopical preparations, the use of the tow-net,

microscopic life in the sea, and the life-history of some common type of marine animal.

A large party, consisting of representatives of the Sea Fisheries Committee and the various Educational Committees of Lancashire, visited the laboratory on April 24th and saw the fishermen at work. An interesting address on the scientific and educational work of the Sea Fisheries Committee as applied to fishermen was given by Mr. A. T. Wright, and was greatly appreciated by the audience. Mr. Walter E. Archer, Assistant Secretary to the Department of Agriculture and Fisheries, inspected the establishment in April. Mr. M. A. Fenton, one of H.M. Inspectors of Schools, visited the laboratory to inspect and report on the work of the classes for fishermen and school teachers

A good deal of time has been devoted to the examination of the pelagic organisms in the Irish Sea around the Isle of Man, and from there to Lancashire and to Cardigan Bay, which were collected by various kinds of nets at depths ranging between the surface and 60-70 fathoms. In fact, 1907 makes a record for this part of our work. In 1906 the number of plankton samples collected and examined was just four hundred, while in 1907 that total was fully doubled, as is shown by the following figures:—

Ordinary tow-net collections by the			
Fisheries steamer	...	...	160
Hensen Net, monthly observations	...	...	27
Fishery officers in Cardigan Bay,			
ordinary tow-net—	...	...	60
Samples taken by various nets around the			
Isle of Man by Professor Herdman,			
and in Port Erin Bay by Mr. Chad-			
wick and others	...	...	638
Collections made round the West of			
Scotland by Professor Herdman	...	...	10
Total...			895



Owing to the necessary arrangements in contemplation of the sale of the former Fisheries steamer and the delay in delivery of the "James Fletcher," Captain Wignall's collections could not be so systematically made as in former years, and the number is naturally reduced in consequence. The results of the monthly observations with the Hensen net and of the extensive series of collections taken by Professor Herdman from the S.Y. "Ladybird," are dealt with elsewhere in this report. The other collections are in process of being worked up, and reports upon them will be given later.

## MONTHLY INVESTIGATION OF THE PLANKTON BY THE HENSEN NET METHOD.

BY ANDREW SCOTT.

This investigation was commenced in January, 1907, with the intention that regular hauls should be taken at intervals of one month, between Piel Gas Buoy, at the outside entrance to the Barrow Channel, and Great Ormes Head, on the North Wales coast. Owing to unforeseen circumstances the continuity of the observations was interrupted on three occasions: no hauls were taken in April, July and December. In the absence of a complete series of monthly observations it would be unwise in the present report to discuss the changes that take place, from month to month, in the pelagic organisms along the line of observation. At the same time, one or two interesting facts can be detected by a review of the tables of results given below, which are worth some attention.

Three stations have been laid down along an imaginary straight line, joining Piel Gas Buoy to Great Ormes Head. The first station is four and a half miles, the second twenty-two and a half, and the third forty and a half miles from Piel Gas Buoy. The third station is four and a half miles off the Orme's Head, and the middle station is eighteen miles equidistant from the first and third. At each station the ship is stopped, and when all way is off her the net is put over the side, lowered down to a depth of ten fathoms and then slowly drawn to the surface. The time taken to draw the net up through ten

fathoms is about sixty-five seconds. The net is then got on board and the ship continues her course to the next station. As soon as the net comes on board, the contents of the metal bucket, provided with a tap at the end of it, are run off through a fine silk filter of the same texture as the net. The tap is then shut and the outside of the net well washed down with the ship's hosepipe. In this washing of the net, the bucket is again filled with the water that passes *through* the silk, and any organism adhering to the inside of the net after the first straining are taken into the bucket with the washings. The contents of the bucket are again passed through the silk filter and the whole catch and silk of the filter are at once transferred to 3 per cent. formalin in sea water and labelled. The samples are afterwards carefully examined ashore. For an explanation of the methods now adopted in the investigation of our plankton samples, see the joint report on the plankton taken off the Isle of Man by Professor Herdman and myself.

The first point to be noted, is that the amount of life in the sea during the early months of the year is very small, from May on to September there is a great increase in bulk, and then towards the end of the year it falls away. The nine hauls taken in the first quarter of the year gave nineteen cubic centimetres of organisms, while the three hauls taken in September caught eighty cubic centimetres altogether.

Next, taking the organisms in order, we find that in January, Diatoms were scarce and only represented by two species. In February a considerable increase in numbers was found and thirteen species were present along our line of observation. A further increase was found in March and twenty species were noted. Diatoms further increased in May and the species represented reached a

total of twenty-six. In June, although the species present had fallen to nineteen, the number noted was high, and the bulk of the plant life consisted of *Eucampia* and *Rhizosolenia*. In August and September the Diatoms continued to be very abundant and the species represented were nearly as numerous as in May. In October there was a marked decrease in numbers and the species had fallen to twenty. An apparent recovery was found to have taken place in November, and the number of Diatoms taken in the three hauls was fully twice that found in the three hauls for October. During October and November there were more Diatoms in the vicinity of Walney than at the other two stations, and the central region contained the least. It will be noted that the hauls taken in October yielded  $3\frac{1}{2}$ , 17 and 5 cubic centimetres of organisms respectively, yet the numbers of Diatoms were completely inverted, as the following figures show: ( $3\frac{1}{2}$ ) 24·300; (17) 7·450; (5) 12·700.

Species of *Ceratium* were present in eight out of the nine monthly hauls. They appeared to be entirely absent in the whole area in January and at Station I in February. It will be noticed from the tables that from the month of June to the end of the series, these organisms were more abundant at Station I than at either the second or third. It is evident that there is a distinct maximum period in August. Specimens of *Peridinium* were much scarcer than those of *Ceratium*, and apparently reached their maximum point a little earlier in the year.

*Noctiluca* has been recorded in our reports for some years as occurring in large numbers along the North Wales and Lancashire coasts during the summer and autumn months.

The specimens found in the hauls for January, February and March were probably survivors from the



summer of 1906, as none were observed in May. The organism was present at all the stations in June, and in large numbers again in August and September. The hauls taken in October showed a decided decrease, which became still more marked in November. It is probable that the maximum point of the invasion was reached about the end of August. The bulk of the samples taken in August and September consisted of *Noctiluca*.

Specimens of *Sagitta* were present in the area in each of the months that collections were taken, and only once appeared to be absent from any of the three stations. The largest number of specimens were taken in September. Copepoda apparently follow pretty much the same increase as the other groups, and the largest numbers were found in the September hauls.

When a complete series of hauls with the Hensen net along this line is available for comparison, it will be possible to discuss more fully the changes that take place from month to month amongst the organisms that make their appearance in the upper layers of the sea throughout the year.

Station and Date.—Hensen Net Stations, January  
8th and February 5th, 1907.

Depth in fathoms .....	10-0	10-0	10-0	10-0	10-0	10-0
Catch in c.cm. ....	2	3	2	2	3	2
Stations .....	I.	II.	III.	I.	II.	III.
<i>Asterionella bleakeleyi</i> ...	—	—	—	—	—	25
<i>Biddulphia mobiliensis</i> .....	—	—	8	800	570	800
<i>Chætoceros decipiens</i> .....	—	—	—	600	200	100
<i>Coscinodiscus concinnus</i> ...	25	6	58	500	500	550
„ <i>granii</i> .....	—	—	—	24	20	—
<i>Ditylium brightwellii</i> .....	—	—	—	30	—	—
<i>Melosira borreri</i> .....	—	—	—	8	—	—
<i>Rhizosolenia semispina</i> ...	—	—	—	30	30	100
„ <i>setigera</i> .....	—	—	—	20	10	—
„ <i>shrubsolei</i> ...	—	—	—	—	—	25
<i>Bacillaria paradoxa</i> .....	—	—	—	12	—	100
<i>Bellerochea malleus</i> .....	—	—	—	15	3	—
<i>Nitzschia closterium</i> .....	—	—	—	—	10	75
<i>Trochiscia</i> sp. ....	—	—	—	—	—	25
<i>Ceratium furca</i> .....	—	—	—	—	10	50
„ <i>fuscus</i> .....	—	—	—	—	20	100
„ <i>tripos</i> .....	—	—	—	—	200	50
<i>Noctiluca miliaris</i> .....	1	30	100	14	10	—
<i>Pleurobrachia pileus</i> .....	—	—	—	—	—	1
<i>Sagitta bipunctata</i> .....	8	12	56	5	37	8
Larval Polychæta .....	1	—	3	—	—	—
‘ <i>Mitraria</i> ’ .....	—	—	1	—	30	—
<i>Mysis</i> stage of Crangon ...	3	—	—	—	—	—
<i>Microniscus calani</i> .....	—	—	4	—	—	—
<i>Calanus helgolandicus</i> .....	1	1	—	—	—	—
<i>Pseudocalanus elongatus</i> ...	72	30	135	54	3	36
<i>Temora longicornis</i> .....	—	—	—	—	2	3
<i>Centropages hamatus</i> .....	—	—	7	—	—	4
<i>Acartia clausi</i> .....	6	5	18	23	20	13
<i>Oithona similis</i> .....	3	1	5	94	70	90
<i>Paracalanus parvus</i> .....	35	16	119	52	25	15
<i>Thompsonula hyæna</i> .....	—	—	—	3	—	—
Copepod nauplii .....	—	—	—	60	1,290	150
Lamellibranchs, larval .....	—	—	1	—	—	—
<i>Oikopleura</i> sp. ....	1	—	—	—	—	—
Ascidian eggs .....	1	—	—	—	—	—

Station and Date.    Hensen Net Stations, March 5th,  
1907.

Depth in fathoms .....	10-0	10-0	10-0	—	—	—
Catch in c.cm. ....	2	1½	1½	—	—	—
Station .....	I.	II.	III.	—	—	—
<i>Asterionella bleakeleyi</i> ...	—	25	50	—	—	—
<i>Biddulphia mobiliensis</i> .....	500	3,200	3,500	—	—	—
<i>Chaetoceros contortum</i> ...	50	75	75	—	—	—
„ <i>decipiens</i> .....	300	175	255	—	—	—
„ <i>sociale</i> .....	—	50	25	—	—	—
„ <i>teres</i> .....	100	100	150	—	—	—
„ <i>subtile</i> .....	75	—	—	—	—	—
<i>Coscinodiscus concinnus</i> ...	900	630	625	—	—	—
„ <i>granii</i> .....	50	25	50	—	—	—
<i>Ditylium brightwellii</i> .....	150	50	25	—	—	—
<i>Eucampia zodiacus</i> .....	25	—	—	—	—	—
<i>Rhizosolenia setigera</i> .....	—	100	200	—	—	—
„ <i>shrubsolei</i> ...	—	25	75	—	—	—
<i>Actinopterychus splendens</i> ...	50	—	—	—	—	—
<i>Biddulphia aurita</i> .....	800	300	—	—	—	—
„ <i>favus</i> .....	400	75	100	—	—	—
„ <i>granulosa</i> .....	—	400	320	—	—	—
<i>Coscinodiscus radiatus</i> .....	875	1,500	1,600	—	—	—
<i>Leptocylinthus danicus</i> ...	—	25	—	—	—	—
<i>Bacillaria paradoxa</i> .....	—	25	125	—	—	—
<i>Ceratium furca</i> .....	25	—	—	—	—	—
„ <i>fuscus</i> .....	300	400	470	—	—	—
„ <i>tripos</i> .....	550	1,000	420	—	—	—
<i>Peridinium</i> sp. ....	—	25	25	—	—	—
<i>Noctiluca miliaris</i> .....	—	25	—	—	—	—
<i>Pleurobrachia pileus</i> .....	—	—	1	—	—	—
Medusoid gonophores .....	—	—	1	—	—	—
<i>Sagitta bipunctata</i> .....	—	5	8	—	—	—
Larval Polychæta .....	2	50	25	—	—	—
‘Mitraria’ .....	—	25	—	—	—	—
<i>Podon intermedium</i> .....	1	—	—	—	—	—
<i>Pseudocalanus elongatus</i> ...	42	20	25	—	—	—
<i>Temora longicornis</i> .....	1	—	—	—	—	—
<i>Centropages hamatus</i> .....	1	—	—	—	—	—
<i>Acartia clausi</i> .....	20	3	1	—	—	—
<i>Oithona similis</i> .....	3	—	75	—	—	—
<i>Paracalanus parvus</i> .....	3	1	2	—	—	—
<i>Cyclopina littoralis</i> .....	75	—	—	—	—	—
Copepod nauplii .....	775	1,500	1,200	—	—	—
„    metanauplii .....	1	—	—	—	—	—
„    juv. ....	100	50	175	—	—	—
Barnacle nauplii .....	10	—	—	—	—	—
Lamellibranchs, larval ...	—	75	125	—	—	—
<i>Oikopleura</i> sp. ....	1	—	—	—	—	—

## Station and Date.—Hensen Net Stations, May 10 and June 5, 1907.

Depth in fathoms .....	10-0 4½	10-0 4	10-0 14	10-0 5½	10-0 14	10-0 32
Catch in c.cm. ....	I.	II.	III.	I.	II.	III.
Asterionella bleakeleyi ...	—	—	25,000	—	—	—
„ japonica .....	—	—	3,750	—	—	—
Biddulphia mobiliensis.....	30,000	43,500	1,190,000	875	125	65,000
Chatoceros contortum ...	125	—	2,500	—	—	—
„ debile .....	—	1,500	31,000	—	—	—
„ decipiens .....	—	20,000	81,000	3,700	75	50,000
„ densum .....	—	—	—	1,000	—	500
„ sociale .....	5,000	24,000	43,700	1,000	—	500
„ teres .....	1,300	7,500	100,000	8,700	15,000	1,500
„ subtile .....	875	—	—	16,000	15,000	—
„ diversum .....	—	1,000	—	—	—	—
Coscinodiscus concinnus ...	28,000	20,000	213,000	625	2,125	500
„ granii .....	120	100	—	—	—	—
Coscosira polychorda ...	—	—	5,000	1,000	—	—
Ditylum brightwellii .....	1,250	500	25,000	—	—	—
Eucampia zodiacus .....	2,250	5,000	87,500	43,750	4,000,000	73,000
Melosira borreri .....	3,700	1,500	1,250	25,000	100,000	2,000
Rhizosolenia semispina ...	87,000	167,000	22,500	2,000,000	2,000,000	85,000
„ setigera .....	22,000	12,000	37,000	6,250	2,500	—
„ shrubsolei ...	12,000	3,500	50,000	63,000	650,000	70,000
„ stouterfothii.....	—	—	—	—	10,000	1,000
Biddulphia aurita .....	500	—	—	—	2,500	—
„ granulosa .....	1,250	500	1,250	—	—	500
Coscinodiscus radiatus .....	15,000	11,500	37,500	1,230	3,500	875
Bacillaria paradoxa .....	—	—	1,250	—	—	—
Guinardia flaccida.....	130	500	2,500	2,500	63,000	9,000
Lauderia borealis .....	500	500	12,500	—	2,500	1,500
Streptotheca thamensis ...	—	—	2,500	—	—	—
Ceratium furca .....	120	100	—	2,500	1,000	—
„ fusus .....	5,000	5,500	7,500	13,750	2,500	3,000
„ tripos.....	1,600	2,000	2,500	13,750	7,500	1,000
Peridinium sp. ....	2	500	—	23,500	6,250	1,500
Trochiscia sp. ....	875	1,000	2,500	2,500	2,500	3,500
Noctiluca miliaris .....	—	—	—	1,250	2,000	2,500
Pleurobrachia pileus .....	—	—	—	3	7	6
Medusoid gonophores .....	3	12	6	6	70	110
Plutei of Echinoderms ...	—	—	—	—	125	—
Sagitta bipunctata .....	3	4	7	23	31	30
Larval Polychæta .....	670	1,000	545	440	155	80
'Mitraria' .....	250	100	—	—	—	—
Crab zoea .....	3	1	3	10	8	3
Mysis stage of Crangon .....	3	2	5	1	—	6
Second stage Nephrops ...	—	—	—	—	—	1
Podon intermedium .....	—	—	—	40	—	—
Evadne nordmanni .....	—	—	—	20	1	—
Calanus helgolandicus .....	1	—	—	—	—	—
Pseudocalanus elongatus ...	10	65	25	180	170	60
Temora longicornis .....	120	75	115	450	1,250	1,780
Centropages hamatus .....	25	120	30	30	250	1,200
Acartia clausi .....	75	5	10	300	200	30
Oithona similis .....	125	—	—	10	—	250
Paracalanus parvus .....	—	5	5	10	20	—
Isias clavipes .....	—	—	—	—	—	100
Copepod nauplii .....	13,250	700	9,000	11,250	11,250	500
„ juv. ....	625	500	1,300	2,500	3,750	6,000
Barnacle nauplii .....	38	5	70	25	20	20
„ cypris stage .....	—	—	3	—	2	6
Gasteropods, larval .....	125	125	—	375	375	—
Lamellibranchs, larval ...	250	250	1,250	3,750	—	500
Oikopleura sp. ....	120	4	2	1,150	1,300	1,350
Ascidian eggs .....	—	—	—	250	—	—
Grey Gurnard eggs .....	—	—	2	—	1	—
Solenette eggs .....	—	—	—	—	1	—
Post larval Plaice.....	—	2	—	—	—	—
„ „ Liparis .....	—	—	—	1	—	—
„ „ sp. ....	—	—	—	—	1	—
„ „ sp. ....	—	—	—	—	2	—



## Station and Date.—Hensen Net Stations, Aug. 29 and Sept. 18, 1907.

Net used .....	—	—	—	—	—	—
Depth in fathoms .....	10-0	10-0	10-0	10-0	10-0	10-0
Catch in c.cm. ....	11½	40	13	26	28	28
Station .....	I.	II.	III.	I.	II.	III.
<i>Asterionella bleakeleyi</i> .....	—	—	750	—	—	500
<i>Biddulphia mobilensis</i> .....	18,000	—	31,000	—	—	1,000
„ <i>aurita</i> .....	—	—	1,000	—	—	—
<i>Chætoceros contortum</i> ..	—	—	—	12,500	500	—
„ <i>debile</i> .....	2,000	750	—	5,000	—	—
„ <i>decipiens</i> .....	5,000	—	1,500	—	500	—
„ <i>sociale</i> .....	—	1,000	2,250	325,000	170,000	—
„ <i>teres</i> .....	1,000	1,000	7,500	75,000	3,000	—
„ <i>densum</i> .....	110,000	185,000	63,750	150,000	3,000	500
„ <i>boreale</i> .....	—	—	6,750	7,500	2,500	—
„ <i>subtile</i> .....	—	—	—	2,500	—	—
<i>Coscinodiscus concinnus</i> ..	6,000	5,000	250	35,000	4,700	1,000
<i>Ditylum brightwellii</i> .....	—	—	1,500	—	—	—
<i>Eucampia zodiacus</i> .....	500	5,000	—	—	70,000	1,000
<i>Leptocylindrus danicus</i> ..	1,000	150,000	750	10,000	2,000	—
<i>Melosira borreri</i> .....	—	—	—	5,000	500	—
<i>Lauderia borealis</i> .....	—	—	—	5,000	500	—
<i>Rhizosolenia semispina</i> ..	71,000	—	173,000	250,000	5,000	3,500
„ <i>setigera</i> .....	3,500	5,000	—	—	—	—
„ <i>shrubsolai</i> ..	190,000	165,000	9,750	12,500	2,500	3,500
„ <i>stolterfothii</i> .....	2,500	—	1,500	2,500	500	2,000
<i>Biddulphia granulosa</i> .....	1,500	—	2,750	—	—	—
„ <i>favus</i> .....	500	—	250	—	—	—
„ <i>rhombus</i> .....	1,000	—	—	5,000	—	—
<i>Coscinodiscus radiatus</i> ..	7,500	—	5,500	10,000	1,000	—
<i>Guinardia flaccida</i> .....	285,000	1,800,000	34,500	—	3,000	171,000
<i>Bacteriastrium</i> sp. ....	3,000	300,000	750	37,500	9,000	—
<i>Bacillaria paradoxa</i> .....	—	—	—	12,500	—	—
<i>Nitzschia seriata</i> .....	1,000	—	3,000	12,500	—	—
<i>Streptothecca thamensis</i> ..	—	—	1,500	—	—	—
<i>Bellerochea malleus</i> .....	500	—	—	—	—	—
<i>Ceratium furca</i> .....	71,000	2,000	250	12,500	1,000	—
„ <i>fuscus</i> .....	690,000	31,000	124,000	225,000	6,000	1,000
„ <i>tripos</i> .....	140,000	2,625	7,000	170,000	10,000	2,500
<i>Peridinium</i> sp. ....	2,000	—	250	10,000	1,500	1,000
<i>Trochiscia</i> sp. ....	3,750	370	7,700	—	—	—
<i>Distephanus</i> sp. ....	1,000	—	—	—	—	—
<i>Tintinnopsis</i> sp. ....	3,000	—	—	2,500	—	—
<i>Noctiluca miliaris</i> .....	27,000	183,000	54,000	22,500	140,000	138,000
<i>Pleurobrachia pileus</i> .....	1	—	—	2	2	8
Medusoid gonophores .....	20	37	5	200	160	15
Plutei of Echinoderms ..	1,510	—	—	1,250	—	—
<i>Sagitta bipunctata</i> .....	40	300	5	1,000	700	300
Larval Polychæta .....	3,100	200	3,750	7,800	560	530
'Mitraria' .....	—	15	500	—	—	200
Crab zoea .....	—	37	—	—	3	—
„ <i>megalo</i> .....	—	—	—	—	—	2
Mysis stage of Crangon ..	—	37	2	—	1	75
Podon intermedium .....	—	—	—	40	20	—
<i>Calanus helgolandicus</i> .....	—	—	—	—	5	4
<i>Pseudocalanus elongatus</i> ..	20	300	5	—	—	—
<i>Temora longicornis</i> .....	230	1,400	350	160	160	2,500
<i>Centropages hamatus</i> .....	100	110	310	60	60	400
<i>Anomalocera pattersoni</i> ..	—	—	—	—	1	—
<i>Acartia clausi</i> .....	130	600	125	100	500	900
<i>Oithona similis</i> .....	2,530	5,000	520	12,500	11,400	16,000
<i>Paracalanus parvus</i> .....	50	700	10	1,000	4,000	2,300
<i>Isias clavipes</i> .....	—	900	20	—	20	30
Copepod nauplii .....	15,000	35,000	12,800	20,000	6,500	3,500
„ juv. ....	6,000	55,000	8,215	7,500	175,000	18,500
Gasteropods, larval .....	500	—	750	1,250	—	—
Lamellibranchs, larval ..	500	1,000	4,250	2,500	4,500	3,500
<i>Oikopleura</i> sp. ....	1,580	4,000	3,000	2,560	1,000	3,400
Ascidian eggs .....	1,500	370	—	—	—	100

Station and Date.—Hensen Net Stations, October 7th  
and November 18th, 1907.

Net used .....	—	—	—	—	—	—
Depth in fathoms .....	10-0	10-0	10-0	10-0	10-0	10-0
Catch in c.cm. ....	3½	17	5	3½	3	2
Stations .....	I.	II.	III.	I.	II.	III.
<i>Biddulphia mobiliensis</i> .....	200	50	275	450	3,900	11,000
<i>Chaetoceros contortum</i> ...	50	—	—	2,000	150	100
„ <i>debile</i> .....	250	—	—	500	75	50
„ <i>decipiens</i> .....	350	—	100	17,500	1,600	750
„ <i>teres</i> .....	1,000	250	—	6,000	375	450
„ <i>densum</i> .....	750	750	325	1,250	600	400
„ <i>boreale</i> .....	1,500	250	—	—	—	—
„ <i>subtile</i> .....	300	—	—	750	—	—
<i>Coscinodiscus concinnus</i> ...	1,000	100	225	5,550	750	1,500
<i>Ditylium brightwellii</i> .....	100	—	—	—	—	50
<i>Eucampia zodiacus</i> .....	50	—	—	1,000	75	450
<i>Leptocylindrus danicus</i> ...	—	—	—	75	—	—
<i>Melosira borneri</i> .....	200	—	—	—	—	50
<i>Pleurosigma</i> sp. ....	—	—	—	—	25	—
<i>Rhizosolenia semispina</i> ...	9,000	750	25	1,000	750	150
„ <i>setigera</i> .....	1,850	—	—	150	300	250
„ <i>shrubsolei</i> ...	1,100	—	25	600	—	250
<i>Lauderia borealis</i> .....	—	—	—	—	—	50
<i>Bacillaria paradoxa</i> .....	400	—	20	250	75	—
<i>Bacteriastrium</i> sp. ....	5,750	5,200	175	4,250	1,125	980
<i>Biddulphia rhombus</i> .....	300	—	—	150	25	—
„ <i>granulosa</i> .....	—	—	—	75	150	—
„ <i>favus</i> .....	—	—	—	—	25	—
<i>Coscinodiscus granii</i> .....	—	—	—	190	75	100
„ <i>radiatus</i> .....	150	250	25	—	225	100
<i>Guinardia flaccida</i> .....	—	50	75	75	75	100
<i>Ceratium furca</i> .....	—	—	—	225	75	—
„ <i>fuscus</i> .....	750	250	125	975	375	650
„ <i>tripos</i> .....	8,650	50	825	2,700	1,720	1,500
<i>Hexasterias</i> sp. ....	50	—	—	—	—	—
<i>Trochiscia</i> sp. ....	100	—	—	—	75	—
<i>Tintinnopsis</i> sp.....	300	1,750	25	250	—	—
<i>Noctiluca miliaris</i> .....	10,000	100,000	7,800	1,300	1,335	500
<i>Pleurobrachia pileus</i> .....	—	3	—	1	—	—
Medusoid gonophores .....	1	10	3	10	2	6
Plutei of Echinoderms ...	—	250	—	—	—	—
<i>Sagitta bipunctata</i> .....	6	250	200	35	30	16
<i>Autolytus prolifer</i> .....	1	—	—	—	—	—
Larval Polychæta .....	580	50	55	225	30	55
'Mitraria' .....	50	250	50	75	—	600
Crab zoea .....	—	—	1	—	—	—
„ <i>megalopa</i> .....	—	—	1	—	—	—
Mysis stage of Crangon ...	1	—	5	3	—	—
<i>Calanus helgolandicus</i> .....	—	—	—	15	1	1
<i>Pseudocalanus elongatus</i> ...	20	250	130	10	30	35
<i>Temora longicornis</i> .....	17	50	10	5	4	80
<i>Centropages hamatus</i> .....	25	50	—	5	1	65
<i>Acartia clausi</i> .....	—	450	275	85	90	55
<i>Oithona similis</i> .....	2,780	1,000	2,600	3,310	2,300	530
<i>Paracalanus parvus</i> .....	160	13,000	2,450	665	425	—
<i>Isias clavipes</i> .....	—	—	1	—	—	—
<i>Euterpina acutifrons</i> .....	—	—	—	—	—	3
Copepod nauplii .....	500	500	100	225	225	300
„ <i>juv.</i> .....	2,000	12,500	1,375	4,250	450	350
Gasteropods, larval .....	100	250	50	75	75	100
Lamellibranchs, larval ...	650	1,750	1,000	2,625	225	500
<i>Oikopleura</i> sp. ....	480	1,600	300	150	10	150
Ascidian eggs .....	—	250	—	—	—	—

REPORT ON EXPERIMENTS WITH MARKED  
FISHES DURING THE YEAR, 1907.

(Plates I and II).

By JAS. JOHNSTONE.

It was only possible, for various reasons, to continue these experiments during 1907 on a less extensive scale than during 1905-6. We resolved to concentrate the experiments as far as possible, and to confine our attention to the summer plaice fishery in Liverpool Bay, and to the autumn and winter plaice fishery that is carried on in Red Wharf Bay and in Channel Course. Three experiments were therefore made, (1) in Menai Straits in February, 1907, when about 100 small plaice were caught by the "John Fell" and liberated close to the place of capture; (2) near Nelson Buoy at the entrance to the Ribble Estuary in July, 1907, when about 150 plaice were caught, also by the "John Fell," and liberated on the ground where taken; and (3) in Red Wharf and Beaumaris Bays in October, 1907, where 120 plaice were caught and liberated. I intended to mark and liberate plaice and flounders in the neighbourhood of the Lune and Wyre Rivers, and in Barrow Channel, but did not find this possible because of the other engagements of the "John Fell" and the Fleetwood police cutter. In June a number of plaice which had been kept during the preceding year in the spawning pond, at the Port Erin Hatchery, were turned out into the sea, and at Prof. Herdman's request I sent a number of labels to Mr. Chadwick, Curator of the Biological Station, who then marked 28 large plaice and liberated them near Bradda Head.

During 1907 we, therefore, marked 360 fishes, all plaice with one exception, and at the time of writing (16th

December) 102 of these have been returned to me. In addition to these fishes 47 others marked and liberated during 1905 and 1906 have also been returned, making 149 recaptures in all. No attempt was made to mark other fishes than plaice during 1907, but we hope in the coming year to devote some attention to flounders. As in former years, I am convinced that quite a number of marked plaice are captured and are not reported to me. One hears, now and then, of fish that have been captured for some time, and it is curious that over and over again marked plaice are recaptured by the same boats. One could draw up a list of smacks that have caught what is apparently far more than their share of marked fishes, and I am inclined to suspect that many fishes, caught perhaps during the dark, are not noticed. Most of the fishermen on the West Coast of England must now know about these experiments, but it appears that until a skipper has caught one or more marked fish he and his men do not examine their catches so carefully as to avoid the risk of a marked fish going unnoticed.

As before, I am greatly indebted to those who have taken the trouble to send me marked fishes handed to them. This applies particularly to Messrs. Harley and Miller, of the Liverpool Fish Market, Messrs. Dean and Houldsworth (members of the Committee); Mr. Robert Knox, of Douglas; and Mr. A. J. Rust, of Milford Haven. Captain Jones, Head Bailiff at the Carnarvon Station, has also taken a great amount of trouble to forward me all fish given to him, and has been most careful in supplying all the necessary information of recapture, &c.

I give all the details of recapture in the tables that follow. The "general summary" gives the total results of the experiments of the year, and includes, also, marked fishes which have been liberated in 1905 and 1906. The



following tables give the details of recapture and growth of the fishes returned. The "analyses of sizes of fish recaptured" give the numbers of plaice of each size group (every quarter of an inch) marked and liberated; it will be seen that the majority of the plaice dealt with were between 9 and 11 inches in length. In the tables of "particulars of fishes returned" the columns are numbered in order to save space. The headings are:—

1	2	3	4	5	6	7	8
No. of label	Size when liberated (inches)	Place of recapture	Date of recapture	Months in the Sea	Length when recaptured (inches)	Increase in length (inches)	Method of recapture

The lengths of the fishes when marked were measured to the nearest quarter of an inch. The lengths when returned were measured to the nearest eighth of an inch. When only one or two fishes are returned in any particular month an error may result from this difference in the accuracy of the two measurements, but when average growth-increments are calculated, and when these are plotted on a curve, and the latter smoothed, such inaccuracies disappear. The place of recapture is usually given as reported to me. It is generally unlikely that it is accurate to within a mile or two, as a fish may be caught anywhere during a drag of the trawl-net, which may be of 20 or more miles in length in the case of a steam trawler. As a rule, however, such inaccuracies in position have no real significance. The values, "months in the sea," have been obtained by subtracting the number of the month of liberation from that of recapture: they are calendar months. The letters under heading 8, "method of recapture," denote:—ST, steam

trawler; 1T, 1st class trawler; 2T, 2nd class trawler; SN, stake net; TN, trammel net; DN, draw net or seine net. The greater number of the fishes returned were recaptured by means of trawl nets used by 1st and 2nd class trawlers. In some cases this information as to the method of recapture was not given; in one or two cases it was also impossible to trace the position of recapture. Whenever possible the fishes were weighed, but very often they had been gutted before being forwarded, so that it was not practicable to estimate the weight in every case. In the case of every fish sent, the otoliths were removed, and are being kept with the object of determining the mode of growth of these structures in relation to the season.

GENERAL SUMMARY:—  
STATIONS AND NUMBERS OF FISHES LIBERATED AND RETURNED.

	Place where Fishes Liberated.	Date.	No. Liberated.	No. Returned.	Percentage Returned.
1	Eastern Entrance to Menai Straits .....	6/2/07	92 plaice	29	31·5
2	2 miles N. from Bradda Head, Isle of Man .....	1/6/07	28 plaice	—	—
3	Near Nelson Buoy, Entrance to Ribble .....	3/7/07	147 plaice 1 brill	36	24·5
4	Beaumaris Bay .....	24/10/07	120 plaice	37	30·8
	Totals, Experiments of 1907 .....		360*	102	28·3†
	Experiments of 1906 .....		—	45	—
	Experiments of 1905 .....		—	2	—
	Totals .....		—	149	—

\* Includes only the fishes liberated on the Lancashire and Welsh coasts.

† Calculated from Lancashire and Welsh experiments only.

## DETAILS OF FISHES RETURNED.

## Experiments of 1906.

The following fishes, returned in 1907, are to be added to the lists given in the last Annual Report.

Experiment 2, 19th February, 1906.

Station: Near Fleetwood. 35 plaice.

1	2	3	4	5	6	7	8
L752	11½	Off Dundalk, E. coast of Ireland	26/11/06	9	14	2¾	ST
L768	11	Not known .....	8/3/07	13	15½	4¾	—
L769	9	1½ miles E. from Corsewall, Clyde, 12 faths.	18/4/07	14	11	2	—

The results of this experiment were discussed in last year's Report, but several recaptures have been made during the present year and some doubtful cases have been traced. It may be useful, therefore, to summarise the results anew. Eighteen of the 35 plaice liberated, or over 51 per cent., have been returned, and it will be seen that the positions of recapture are distributed over a considerable area, one fish being taken in the Firth of Clyde, and one off the East Coast of Ireland. It will be noticed that a group of eight fishes have been recaptured in inshore waters during the four months after the date of liberation. Two of these had migrated to the South, but were recaptured still in shallow water inshore, while six fishes were taken in almost the same place where those liberated were originally caught. Then we have a group of seven fishes recaptured much further offshore and in relatively deep water, and all from seven to ten months after the date of liberation. Finally, three fishes are included in this year's recaptures: one taken near Dundalk, one in the Firth of Clyde, and one taken probably by a steam trawler not far from Morecambe



Bay Lightship. On Plate I these three latter recaptures are indicated by large round spots. I think that the results of this experiment indicate those that might be expected if it were practicable to mark and liberate a very large number of plaice on the inshore grounds during the early months of the year, that is, that these fishes would remain there until the end of the spring, to be caught by the stake-nets or inshore trawlers, and then, as they began to experience the season's growth, they would gradually move offshore into deeper water, and would not again return into the shallow bays and estuaries. Unfortunately, it is not easy to obtain a sufficiently large number of small plaice by trawling in the estuaries during January and February, and I can only suggest that the fish should be caught by stake-nets, and taken alive into Piel Hatchery to be marked.

Experiment 5, 5th March, 1906.

Station: Near Blackpool.

1	2	3	4	5	6	7	8
L948	13F	Lune, near No. 3 Buoy	21/9/07	18	14	1	DN
L949	13½F	Near Arnside, Morecambe Bay.	21/8/07	17	—	—	—
L953	9¾	20 miles N.E. from Bahama Light Ship, 24 fathoms.	11/5/07	14	14½	4¾	1T
L971	8¾	5 miles E. from Bahama Light Ship.	30/5/07	14	11¾	3¾	ST
L980	11F	"Point of Shoals." .....	25/3/07	12	12½	1½	ST

Experiment 6, 6th March, 1906.

Station: Colwyn Bay.

1	2	3	4	5	6	7	8
LL21	8¼	E. from Bahama Light.	19/4/07	13	—	—	1T
LL38	8¼	Red Wharf Bay, 12 fathoms.	14/12/06	9	10¾	2½	1T

## Experiment 8, 31st March, 1906.

Station: Outside Walney Island.

1	2	3	4	5	6	7	8
LL103	7 $\frac{1}{4}$	5 miles S.S.E. from Bahama Lightship.	21/12/06	9	9 $\frac{1}{4}$	2	ST

## Experiment 10, 12th June, 1906.

Station: Near Nelson Buoy.

1	2	3	4	5	6	7	8
LL186	8 $\frac{1}{2}$	15 miles off Coningbeg Lightship.	6/7/07	13	12 $\frac{5}{8}$	4 $\frac{1}{8}$	1T
LL187	9 $\frac{1}{4}$	Off Eastham, River Mersey, 11 fathoms.	19/12/06	6	11 $\frac{1}{8}$	1 $\frac{7}{8}$	2T
LL190	9 $\frac{1}{2}$	Not known .....	22/1/07	7	—	—	—
LL192	8 $\frac{3}{4}$	6 miles S. from Bahama Light Ship.	22/12/06	6	?10	1 $\frac{1}{4}$	ST
LL198	8 $\frac{1}{2}$	10 miles S.S.E. from Mine Head, S. coast Ireland, 38 fathoms.	17/3/07	9	12 $\frac{3}{8}$	4 $\frac{1}{8}$	1T
LL204	8 $\frac{3}{4}$	S.W. from Caldy Island, 26 fathoms.	1/8/07	14	12 $\frac{3}{8}$	3 $\frac{7}{8}$	1T

## Experiment 15, 9th July, 1906.

Station: Near Nelson Buoy.

1	2	3	4	5	6	7	8
LL261	8 $\frac{1}{2}$	Off Kinsale Head to S.E. by E., 46 fathoms.	8/4/07	19	10 $\frac{3}{4}$	2 $\frac{1}{4}$	ST
LL266	9 $\frac{1}{4}$	Off Nelson Buoy, 9 faths.	12/6/07	11	10 $\frac{3}{4}$	1 $\frac{1}{2}$	2T
LL269	9	Off Caldy Island. ....	4/7/07	12	11 $\frac{3}{8}$	2 $\frac{5}{8}$	1T
LL276	8 $\frac{1}{2}$	4 miles N.W. from Nelson Buoy.	12/6/07	11	?10	1 $\frac{1}{2}$	1T
LL280	9	6 miles S.S.W. from Morecambe Bay Light Ship.	23/7/07	12	?13	4	1T
LL289	8 $\frac{1}{4}$	6 miles S.E. from Bahama Light Ship	9/12/06	5	10 $\frac{1}{2}$	2 $\frac{1}{4}$	ST
LL297	8 $\frac{1}{4}$	2 miles E. from Liverpool Bar Light Ship.	7/7/07	12	10 $\frac{3}{4}$	2 $\frac{1}{2}$	1T

The results of Experiments 10 and 15 of 1906 also confirm the conclusion that the plaice reared on the Lancashire shallow water grounds move offshore with increasing age and do not return. The recaptures in 1907 from these two experiments are indicated on Plate II by the black spots, and it will be seen that of the plaice liberated in 1906 near Nelson Buoy only two were recaught on nearly the same grounds in 1907. On the other hand, two of these plaice were recaught in 1907 to the S.E. off Maughold Head; and six have been recaught off the S.E. coast of Ireland. All the latter are, compared with the plaice recaught off Nelson Buoy (the ground of original capture), large fishes. One fish, the inevitable exception to the others, was found in the River Mersey, as far up as Eastham.

Experiment 11; 13th June, 1906.

Station: Near Pwllheli.

1	2	3	4	5	6	7	8
LL208	9 $\frac{1}{2}$	S.W. from Godreooy, S. coast of Ireland, 20 fathoms.	15/2/07	8	12 $\frac{1}{2}$	2 $\frac{1}{2}$	—

This fish is one of a lot of 40 set free in Tremadoc Bay in the summer of 1906. So far, only three fishes have been recaptured; one near the place of liberation, and two off the Irish coast.

Experiment 12, 14th June, 1906.

Station: Off Llanrhystyd, Cardigan Bay.

1	2	3	4	5	6	7	8
LL247	11 $\frac{1}{2}$	10 miles S. by W. from Coningbeg Light Ship, 38 fathoms.	7/7/07	13	12	$\frac{1}{2}$	ST
LL334	8 $\frac{1}{2}$	4 miles W.N.W. from Aberayron, Cardigan Bay.	26/4/07	10	9 $\frac{3}{4}$	1 $\frac{1}{4}$	1T
LL337	7 $\frac{3}{4}$	Carmarthen Bay, 3-4 fathoms.	18/4/07	10	9 $\frac{1}{4}$	1 $\frac{1}{2}$	2T

## Experiment 13, 16th June, 1906.

Station: Off Dinas Head, Pembrokeshire.

1	2	3	4	5	6	7	8
LL356	14	4 miles N.N.W. from Aberayron, Cardigan Bay.	20/4/07	10	14	0	1T
LL351	13 $\frac{3}{4}$	Newport Bay, 7-8 faths.	5/6/07	12	14 $\frac{3}{4}$	1	1T

## Experiment 16, 12th July, 1906.

Station: Off Penkylan, Tremadoc Bay.

1	2	3	4	5	6	7	8
LL411	8 $\frac{3}{4}$	Near Caldy Island, 20 fathoms.	10/9/07	14	11 $\frac{7}{8}$	3 $\frac{1}{8}$	1T
LL415	9	Pinfold Channel, 2 faths.	18/1/07	6	10 $\frac{5}{8}$	1 $\frac{5}{8}$	2T
LL434	8 $\frac{1}{2}$	Dinas Head, bearing W.S.W., 12 fathoms.	22/6/07	11	11	2 $\frac{1}{2}$	ST

## Experiment 17, 19th September, 1906.

Station: Red Wharf Bay.

1	2	3	4	5	6	7	8
LL440	11 $\frac{1}{4}$	2 miles from St. Patrick's Island.	22/10/07	13	14 $\frac{5}{8}$	3 $\frac{1}{8}$	H
LL446	10 $\frac{1}{4}$	Red Wharf Bay .....	10/1/07	4	—	—	HN
LL450	10 $\frac{3}{4}$	Holyhead Outer Harbour	25/1/07	4	11 $\frac{1}{4}$	$\frac{1}{2}$	TN
LL457	10	Conway Bay, 7 fathoms.	20/10/07	13	13 $\frac{1}{4}$	3 $\frac{1}{4}$	1T
LL459	9 $\frac{1}{4}$	Menai Straits .....	5/3/07	6	9 $\frac{3}{4}$	$\frac{1}{2}$	2T
LL463	10	Holyhead Outer Harbour.	12/1/07	4	10 $\frac{3}{8}$	$\frac{1}{2}$	TN
LL465	9	Red Wharf Bay .....	19/12/06	3	9 $\frac{1}{4}$	$\frac{1}{4}$	1T

These recaptures are indicated in Plate I as red spots. It will be seen that six of the plaice in question



have apparently remained in the neighbourhood of their original place of capture. Five of them were caught at the beginning of this year, or at the end of last year, but one was taken in almost the place where liberated a complete year afterwards. One had crossed the Irish Sea, and was caught off the coast of Ireland.

Experiment 18, 3rd October, 1906.

Station: Luce Bay.

1	2	3	4	5	6	7	8
LL493	12	Luce Bay .....	7/5/07	7	$12\frac{3}{4}$	$\frac{3}{4}$	DN
LL497	$12\frac{1}{4}$	Luce Bay .....	19/7/07	9	$13\frac{1}{4}$	1	DN
LL500	$11\frac{1}{2}$	15 miles S.E. from Maugh-old Head, I.O.M.	27/2/07	4	$11\frac{1}{2}$	0	1T
LL505	$13\frac{1}{2}$	(?) Off Dhu Hearteach, W. coast of Scotland.	25/4/07	6	$13\frac{1}{2}$	0	ST
LL517	13	Near Denure Harbour, Firth of Clyde.	20/11/07	13	$15\frac{1}{2}$	$2\frac{1}{2}$	—

These recaptures exhibit nothing noteworthy. Plaice No. LL505 is recorded just as received, though I think it extremely doubtful whether the information as to the place of recapture is accurate.

Experiment 21, 13th October, 1905.

Station: Luce Bay.

1	2	3	4	5	6	7	8
L872	$10\frac{1}{4}$	Luce Bay .....	20/9/07	23	$15\frac{1}{4}$	5	TN

The following fish was reported to me, but the label (which alone was sent) was entirely corroded away, so that only the silver wire and the bone button were attached to the fish when caught. It is probably one of the Luce Bay fishes liberated in 1904 or 1905.

1	2	3	4	5	6	7	8
—	—	4 miles S.W. from Girvan Harbour, Firth of Clyde.	7/1907	—	—	—	—

### Experiments of 1907.

Experiment 1, 6th February, 1907.

Station: At Eastern Entrance to Menai Straits.

All the fish caught in Menai Straits, and in Beaumaris Bay.

### ANALYSIS OF SIZES OF FISHES LIBERATED.

Size (inches) .....	$7\frac{1}{4}$	$7\frac{1}{2}$	$7\frac{3}{4}$	8	$8\frac{1}{4}$	$8\frac{1}{2}$	$8\frac{3}{4}$	9
No. of plaice .....	2	3	9	10	14	11	10	10
Size (inches) .....	$9\frac{1}{4}$	$9\frac{1}{2}$	$9\frac{3}{4}$	10	$10\frac{1}{2}$	$10\frac{3}{4}$	11	—
No. of plaice .....	3	4	6	5	3	1	1	—

## PARTICULARS OF FISHES RETURNED.

1	2	3	4	5	6	7	8
LL536	10	5 miles N.W. from Jumbo Buoy, 9 fathoms	12/6/07	4	10 $\frac{7}{8}$	$\frac{7}{8}$	2T
LL537	8 $\frac{1}{4}$	Off Holyhead Breakwater, 8 fathoms.	30/3/07	1	9	$\frac{3}{4}$	TN
LL551	8 $\frac{1}{4}$	Dinas Head, bearing W.S. W., 12 fathoms.	20/6/07	4	9 $\frac{3}{4}$	1 $\frac{1}{2}$	1T
LL554	9 $\frac{3}{4}$	Carnarvon Bay .....	13/6/07	4	10 $\frac{1}{4}$	1	1T
LL558	8	8 miles S. by W. from Morecambe Bay Light Ship.	22/8/07	6	10	2	2T
LL559	10 $\frac{1}{2}$	Off Friars, below Beaumaris, 3 fathoms.	30/11/07	9	13 $\frac{7}{8}$	3 $\frac{3}{8}$	2T
LL563	10 $\frac{1}{2}$	Penrhyn Fish Weirs, Menai Straits.	11/5/07	3	11 $\frac{1}{2}$	1	—
LL569	9 $\frac{1}{4}$	Red Wharf Bay .....	5/12/07	7	11 $\frac{3}{8}$	2 $\frac{1}{8}$	1T
LL570	9 $\frac{1}{2}$	Between Newcome Knoll and Deposit Buoy, Entrance to Mersey.	11/10/07	8	12 $\frac{7}{8}$	3 $\frac{3}{8}$	—
LL572	8 $\frac{1}{2}$	Between Point Lynus and Great Ormes Head, 15 fathoms.	14/11/07	9	12 $\frac{1}{4}$	3 $\frac{3}{4}$	1T
LL577	8 $\frac{3}{4}$	Conway Bay, 7 fathoms.	2/11/07	9	—	—	2T
LL582	8 $\frac{1}{4}$	Between Point Lynus and Great Ormes Head, 15 fathoms.	23/10/07	8	9 $\frac{3}{4}$	1 $\frac{1}{2}$	1T
LL589	9 $\frac{3}{4}$	Between Beaumaris and Gallows Point, in Menai Straits.	14/3/07	1	9 $\frac{3}{4}$	0	2T
LL595	7 $\frac{3}{4}$	Carnarvon Bay .....	13/6/07	4	9 $\frac{1}{2}$	1 $\frac{3}{4}$	1T
LL596	8	2 miles N. from N.W. Buoy.	11/6/07	4	9	1	2T
LL598	8 $\frac{1}{4}$	Red Wharf Bay, 10-11 fathoms.	3/12/07	10	11 $\frac{7}{8}$	3 $\frac{5}{8}$	1T
LL651	9 $\frac{1}{2}$	8 miles N. from Morecambe Bay Light Ship.	27/2/07	0	9 $\frac{3}{4}$	$\frac{1}{4}$	1T
LL652	9	Off Deposit Buoy, 5 fathoms.	9/9/07	7	12 $\frac{1}{4}$	3 $\frac{1}{4}$	2T
LL653	8 $\frac{3}{4}$	Red Wharf Bay, 11-12 fathoms.	3/12/07	10	10 $\frac{1}{2}$	1 $\frac{3}{4}$	1T
LL657	8 $\frac{1}{2}$	Between Point Lynus and Great Ormes Head, 20 fathoms.	12/11/07	9	10 $\frac{5}{8}$	2 $\frac{1}{8}$	1T
LL658	11	5 miles W.S.W. from Nelson Buoy	27/9/07	7	13	2	1T
LL659	8 $\frac{1}{4}$	Off Dinorwic, Menai Straits	1/3/07	1	8 $\frac{3}{4}$	$\frac{1}{2}$	2T
LL660	9	Red Wharf Bay .....	4/10/07	8	11 $\frac{1}{2}$	2 $\frac{1}{2}$	1T
LL663	9	Red Wharf Bay .....	8/12/07	7	14	5	1T
LL664	7 $\frac{3}{4}$	Off Beaumaris Pier, 4 fathoms.	25/10/07	8	10 $\frac{1}{2}$	2 $\frac{3}{4}$	DN
LL667	8 $\frac{1}{2}$	10-20 miles S.E. from Bahama Light Ship.	20/7/07	5	10	1 $\frac{1}{2}$	1T
LL668	8	Between Beaumaris and Gallows Point, in Menai Straits, 3 fathoms.	14/3/07	1	8 $\frac{1}{4}$	$\frac{1}{4}$	2T
LL669	8 $\frac{1}{4}$	2 miles N.W. from W. Constable Buoy, 13 fathoms.	7/7/07	5	10 $\frac{1}{2}$	2 $\frac{1}{4}$	1T
LL673	7 $\frac{3}{4}$	Lavan Sands .....	16/10/07	8	—	—	SN

Thus 92 plaice were liberated in the entrance to Menai Straits in February, 1907, and at the end of the same year 29, or about  $31\frac{1}{2}$  per cent., have been returned. The results of the experiment are represented in Plate I, and it will be seen that the recoveries fall roughly into three groups: (1) four fishes caught in Menai Straits during the four months after the date of liberation; (2) eight fishes caught in Liverpool Bay during the summer and autumn; and (3) a group of ten fishes caught in Red Wharf Bay and Channel Course during the late autumn and winter of 1907. One fish was taken in Holyhead Outer Harbour in a trammel net, two fishes were caught in Carnarvon Bay in June, and one fish went as far South as Dinas Head in Pembrokeshire, where it was caught, also in June. Immediately after liberation one fish migrated to the North, and was recaptured not far from Morecambe Bay Light Ship.

### Experiment 2, 1st June, 1907.

Station: Two miles North from Bradda Head, Isle of Man. The plaice marked in this experiment were part of the stock of "spawners" kept during the preceding winter and spring at the Port Erin Hatchery.

#### ANALYSIS OF SIZES OF FISHES LIBERATED.

Size (inches) .....	12	$12\frac{1}{4}$	$12\frac{3}{4}$	13	$13\frac{1}{4}$	$13\frac{1}{2}$	$13\frac{3}{4}$	$14\frac{1}{4}$
No. of plaice .....	2	1	1	1	2	3	1	4

Size (inches) .....	$14\frac{3}{4}$	$15\frac{1}{4}$	$15\frac{1}{2}$	$15\frac{3}{4}$	16	$16\frac{3}{4}$	19	$19\frac{1}{2}$
No. of plaice .....	4	2	2	1	1	1	1	1



None of these plaice have yet been returned. The fishes were marked and liberated by Mr. H. C. Chadwick, of the Port Erin Biological Station. I think it possible that the fishes were enfeebled as a result of long confinement in the spawning pond, and did not survive the marking operation and subsequent handling.

### Experiment 3, 3rd July, 1907.

Station: Near Nelson Buoy, Entrance to Ribble Estuary.

Fish caught near Nelson Buoy.

#### ANALYSIS OF SIZES OF FISHES LIBERATED.

Size (inches) .....	7 $\frac{1}{4}$	7 $\frac{1}{2}$	7 $\frac{3}{4}$	8	8 $\frac{1}{4}$	8 $\frac{1}{2}$	8 $\frac{3}{4}$	9	9 $\frac{1}{4}$
No. of plaice .....	1	1	8	19	25	24	14	9	4
No. of brill .....	—	—	—	—	—	—	—	—	—

Size (inches) .....	9 $\frac{1}{2}$	9 $\frac{3}{4}$	10	10 $\frac{1}{4}$	10 $\frac{3}{4}$	11	11 $\frac{1}{2}$	11 $\frac{3}{4}$	—
No. of plaice .....	15	2	9	8	3	2	2	1	—
No. of brill .....	—	—	—	—	—	1	—	—	—

#### PARTICULARS OF FISHES RETURNED.

1	2	3	4	5	6	7	8
LL689	9 $\frac{1}{2}$	Ribble Bar, 6 fathoms, H.W.	2/12/07	5	10 $\frac{1}{8}$	$\frac{5}{8}$	2T
LL691	8 $\frac{1}{4}$	6 miles N.W. from N.W. Buoy, 6 fathoms.	11/10/07	3	10	1 $\frac{1}{4}$	2T
LL695	10 $\frac{1}{4}$	Heysham Lake, in shallow water.	22/8/07	1	11	$\frac{3}{4}$	DN
LL696	8	1 mile W. from Jumbo Buoy, 6 $\frac{1}{2}$ fathoms.	10/11/07	4	10 $\frac{1}{4}$	2 $\frac{1}{4}$	2T
LL704	7 $\frac{3}{4}$	"Morecambe Bay" .....	11/8/07	1	8 $\frac{1}{8}$	$\frac{3}{8}$	1T
LL709	11 $\frac{1}{2}$	Off Nelson Buoy, 17 faths..	14/8/07	1	—	—	1T
LL711	10	7 miles N.W. from Liverpool N.W. Light Ship, 15 fathoms.	4/8/07	1	10 $\frac{3}{8}$	$\frac{3}{8}$	1T

LL713	8 $\frac{1}{4}$	3 miles W. from Nelson Buoy.	27/7/07	0	9	$\frac{1}{4}$	2T
LL717	8 $\frac{1}{2}$	Liverpool Bar Light Ship bearing S. by E., 15 miles distant, 15 faths.	24/7/07	0	8 $\frac{3}{4}$	$\frac{1}{4}$	1T
LL720	8 $\frac{1}{2}$	2 miles S.W. from Nelson Buoy, 10 fathoms.	13/9/07	2	9	$\frac{1}{2}$	2T
L1 726	8 $\frac{1}{4}$	12 miles N.W. from Liverpool Bar Light Ship, 15 fathoms	8/9/07	2	9 $\frac{1}{2}$	$\frac{3}{4}$	1T
LL730	8 $\frac{1}{2}$	Off Nelson Buoy, 14 faths.	2/8/07	1	8 $\frac{3}{4}$	$\frac{1}{4}$	1T
LL732	8 $\frac{1}{4}$	Roosebeck, Morecambe Bay.	20/11/07	4	9	$\frac{3}{4}$	SN
LL737	8 $\frac{1}{4}$	10 miles N. from Liverpool Bar Light Ship, 14 fathoms.	13/8/07	1	8 $\frac{7}{8}$	$\frac{3}{8}$	1T
LL752	7 $\frac{3}{4}$	3 miles N. from N.W. Buoy, 6 fathoms.	30/8/07	1	9 $\frac{1}{8}$	1 $\frac{3}{8}$	2T
LL758	8 $\frac{1}{4}$	Off Nelson Buoy, 17 faths..	15/8/07	1	8 $\frac{5}{8}$	$\frac{1}{8}$	1T
LL763	10 $\frac{1}{4}$	5 miles W.S.W. from Morecambe Bay Light Ship.	13/7/07	0	—	—	1T
LL764	10 $\frac{1}{4}$	10 miles N. from Liverpool Bar Light Ship, 15 fathoms.	6/8/07	1	10 $\frac{1}{2}$	$\frac{1}{4}$	1T
LL767	8 $\frac{1}{2}$	2 miles N.W. from N.W. Buoy, 6 fathoms.	24/10/07	3	10 $\frac{1}{2}$	2	2T
LL768	9 $\frac{1}{2}$	12 miles from N.W. Light Ship, 17 fathoms.	20/7/07	0	9 $\frac{5}{8}$	$\frac{1}{8}$	1T
LL772	9 $\frac{3}{4}$	10 miles N.W. from Liverpool Bar Light Ship, 19 fathoms.	25/8/07	1	10 $\frac{7}{8}$	1 $\frac{1}{8}$	1T
LL781	10	2 miles W. from Nelson Buoy.	10/7/07	0	10	0	2T
LL782	9	S. Side of Ribble.....	9/11/07	4	11	2	SN
LL783	8 $\frac{1}{4}$	East Hoyle Bank .....	20/11/07	4	11	2 $\frac{1}{4}$	SN
LL792	8	15 miles N.N.W. from Liverpool Bar Light Ship, 17 fathoms.	5/8/07	1	8 $\frac{1}{8}$	$\frac{1}{8}$	1T
LL799	8 $\frac{1}{2}$	Ribble, near Pinfold Buoy, 3 fathoms.	4/12/07	5	10 $\frac{1}{4}$	1 $\frac{3}{4}$	2T
LL806	8 $\frac{1}{2}$	12 miles N.W. from Nelson Buoy, 17 faths.	11/8/07	1	8 $\frac{1}{2}$	0	1T
LL810	8 $\frac{1}{2}$	Off Nelson Buoy, 14 faths..	2/8/07	1	9	$\frac{1}{2}$	1T
LL813	7 $\frac{3}{4}$	3 miles W. from Jumbo Buoy.	30/11/07	4	—	—	2T
LL814	8 $\frac{3}{4}$	Near Lytham Pier .....	16/11/07	4	9 $\frac{1}{4}$	$\frac{1}{2}$	2T
LL817	8 $\frac{1}{4}$	Near No. 5 Buoy in Lune..	29/11/07	4	10 $\frac{1}{2}$	2 $\frac{1}{4}$	2T
LL820	8 $\frac{3}{4}$	2 miles N.W. from N.W. Buoy, 6 fathoms.	24/10/07	3	9 $\frac{3}{4}$	1	2T
LL822	8 $\frac{1}{4}$	Near Jumbo Buoy .....	26/8/07	1	—	—	2T
LL823	8 $\frac{1}{4}$	4 miles N.E. from Liverpool Bar Light Ship, 9 fathoms.	14/10/07	3	9 $\frac{1}{4}$	1	1T
LL824	10	Off Nelson Buoy, 9 faths..	28/9/07	2	—	—	2T
LL827	8	7 miles N. from N.W. Light Ship, 15 fathoms	6/11/07	4	—	—	1T

We see that 147 plaice were liberated in this experiment and that 36, or about  $24\frac{1}{2}$  per cent. have been recaptured up to the present time. In the corresponding experiments of last year on this station 90 plaice in all were liberated, and if we consider the recaptures of this year we find that 42 of these fishes have now been accounted for, that is  $46\frac{1}{2}$  per cent., so we may expect that a number of the fishes liberated in July, 1907, will yet be recaptured. As in former years, most of the fishes liberated near Nelson Buoy in the summer months are recaptured on the fishing grounds to the S. and W., only six fishes have been taken close inshore, and there is a rough indication of a migration to the South and West during the summer and autumn months. It is well known that there is a very intense plaice fishery on the fishery grounds lying roughly between the Liverpool N.W. Light Ship and the Morecambe Bay Light Ship during the months July to October, that is, plaice are very abundant here during the period in question. Now we may ask, where do these fishes come from? and only an imperfect answer to this question is afforded by the results of marking experiments. But if we refer to Plate I, representing the results of Experiment 1, 1907, it will be seen that a number of the fishes set free in the Menai Straits in February, 1907, have been recaptured on the fishing grounds to the W. and S. from Nelson Buoy. I have no doubt that the majority of the fish caught here have migrated out from the shallow water grounds in the bays and estuaries during the spring months, and that the migration is a feeding one, since one finds that the plaice caught there during the summer and autumn fishery always have their stomachs full of food. The results of Experiment 2 of 1906 also lead to the same conclusion, for we find (see Plate I) that some of the fishes caught in the

Lune and Wyre and liberated in February near the place of capture were recaptured during the summer months on the grounds W. from Nelson Buoy. Convincing proof of this offshore migration from the shallow water rearing grounds in the Morecambe Bay area, or in Liverpool Bay, could, of course, be obtained by marking a reasonably large number of fish caught close inshore, but such an experiment would not be easy to carry out unless the fish could be obtained otherwise than by trawling.

### Experiment 4, 24th October, 1907.

Station: In Beaumaris Bay, just outside a line from Puffin Island to Great Ormes Head.

Fish caught in Menai Straits and in Beaumaris Bay.

#### ANALYSIS OF SIZES OF FISHES LIBERATED.

Size (inches). .....	8	8 $\frac{1}{4}$	8 $\frac{1}{2}$	8 $\frac{3}{4}$	9	9 $\frac{1}{4}$	9 $\frac{1}{2}$	9 $\frac{3}{4}$	10	10 $\frac{1}{4}$
No. of plaice .....	3	3	4	4	17	9	14	10	16	8

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Size (inches) .....	10 $\frac{1}{2}$	10 $\frac{3}{4}$	11	11 $\frac{1}{4}$	11 $\frac{1}{2}$	11 $\frac{3}{4}$	12	12 $\frac{1}{4}$	12 $\frac{3}{4}$	—
No. of plaice .....	8	4	6	3	3	1	3	2	2	—

#### PARTICULARS OF FISHES RETURNED.

1	2	3	4	5	6	7	8
LL631	10 $\frac{1}{4}$	Mostyn Deep, Dee .....	22/11/07	1	10 $\frac{1}{4}$	0	2T
LL634	9	Conway Bay, 6 fathoms...	30/10/07	0	9	0	1T
LL639	10 $\frac{1}{2}$	Red Wharf Bay, 7 faths...	25/11/07	1	10 $\frac{1}{2}$	0	1T
LL644	11	Conway Bay, 6 fathoms...	28/10/07	0	11 $\frac{1}{8}$	$\frac{1}{8}$	2T
LL650	9 $\frac{1}{4}$	Near Puffin Island, 8 fathoms.	30/11/07	1	—	—	1T
LL852	11 $\frac{1}{2}$	—	—	—	12 $\frac{1}{8}$	$\frac{5}{8}$	
LL855	12	Red Wharf Bay, 6 faths...	24/11/07	1	12	0	1T
LL861	10 $\frac{1}{4}$	Between Point Lynus and Great Ormes Head, 10 fathoms.	18/11/07	1	—	—	1T



LL862	10	Red Wharf Bay, 10 faths..	3/12/07	—	—	—	IT
LL863	10	Between Point Lynus and Great Ormes Head, 15 fathoms.	14/11/07	1	10 $\frac{1}{4}$	$\frac{1}{4}$	IT
LL864	9 $\frac{1}{4}$	Between Point Lynus and Puffin Island, 9 faths.	18/11/07	1	9 $\frac{3}{8}$	$\frac{1}{8}$	IT
LL874	9 $\frac{3}{4}$	Conway Bay, 4 fathoms...	28/10/07	0	10	$\frac{1}{4}$	2T
LL871	10 $\frac{3}{4}$	Red Wharf Bay, off Moelfre, 5 fathoms .....	12/12/07	2	10 $\frac{7}{8}$	$\frac{1}{8}$	IT
LL884	10 $\frac{1}{2}$	Red Wharf Bay, 10 faths.	3/12/07	2	10 $\frac{1}{2}$	0	IT
LL886	9 $\frac{1}{2}$	Red Wharf Bay, 8 faths.	12/12/07	2	9 $\frac{1}{2}$	$\frac{3}{8}$	IT
LL887	10	Between Point Lynus and Great Ormes Head, 15 fathoms.	12/11/07	1	10	0	IT
LL888	9	Between Point Lynus and Great Ormes Head, 15 fathoms.	14/11/07	1	9 $\frac{1}{8}$	$\frac{1}{8}$	IT
LL892	10	Red Wharf Bay, 7 faths...	25/11/07	1	10	0	IT
LL893	9	Red Wharf Bay, 10-12 fathoms.	4/12/07	2	9 $\frac{1}{2}$	$\frac{1}{2}$	IT
LL894	9	Conway Bay .....	31/10/07	0	—	—	IT
LL899	8 $\frac{1}{2}$	Red Wharf Bay, 11 faths..	12/12/07	2	8 $\frac{5}{8}$	$\frac{1}{8}$	IT
LL900	8 $\frac{1}{4}$	Between Point Lynus and Great Ormes Head, 9 fathoms.	19/11/07	1	—	—	IT
LL901	8	Off Great Ormes Head, 24 fathoms.	21/11/07	1	8 $\frac{1}{4}$	$\frac{1}{4}$	IT
LL902	8 $\frac{1}{2}$	Red Wharf Bay, off Buoy, 10 foot Bank.	12/12/07	2	8 $\frac{1}{2}$	0	IT
LL908	9 $\frac{3}{4}$	Off Red Wharf Bay, 10 fathoms.	3/12/07	2	10	$\frac{1}{4}$	IT
LL913	11	Red Wharf Bay, 10-12 fathoms.	2/12/07	2	11	0	IT
LL914	10 $\frac{1}{4}$	Off Great Ormes Head, 20 fathoms.	7/12/07	2	10 $\frac{3}{8}$	$\frac{1}{8}$	IT
LL921	10	Off Ormes Head, 20 fathoms.	5/12/07	2	10 $\frac{1}{2}$	$\frac{1}{2}$	IT
LL930	10	Conway Bay, 5 fathoms...	22/11/07	1	10	0	2T
LL931	10 $\frac{1}{2}$	Off Puffin Island, 10 fathoms.	5/12/07	2	10 $\frac{1}{8}$	$\frac{1}{8}$	IT
LL933	9 $\frac{3}{4}$	Red Wharf Bay, 10-12 fathoms.	3/12/07	2	10 $\frac{1}{8}$	$\frac{3}{8}$	IT
LL936	9 $\frac{3}{4}$	Mostyn Deep, Dee.....	23/11/07	1	9 $\frac{3}{4}$	0	2T
LL938	10	Red Wharf Bay, 10 faths..	8/12/06	2	10	0	IT
LL940	9	Off Red Wharf Bay, 10 fathoms.	3/12/07	2	9	0	IT
LL942	9	Red Wharf Bay, 12 faths..	3/12/07	2	9 $\frac{3}{8}$	$\frac{3}{8}$	IT
LL943	10	Near Puffin Island, 9 fathoms.	1/12/07	2	10 $\frac{1}{2}$	$\frac{1}{2}$	IT
LL950	9 $\frac{1}{4}$	Wild Roads, off Green- field, Dee.	13/12/07	2	9 $\frac{1}{4}$	0	2T

Experiment 4 was made about the end of October, just before the beginning of the plaice fishery, which usually sets in in the autumn and early winter in Red Wharf Bay

and in Channel Course. One hundred and twenty plaice were marked and liberated, and up to the time of writing 37 of these have been returned to me—that is, in less than two months nearly 31 per cent. of these fishes have been recaught. The results of this experiment are represented in Plate II, and it will be seen that, with a few exceptions, all the fishes returned have been caught in the immediate neighbourhood of the place of liberation. Three plaice have migrated off shore, and three have travelled along the coast, and have been recaught in the Dee. The large red spots on the Chart represent the recapture of fish liberated in Red Wharf Bay in September, 1906, but of these five were recaught at the end of that year and the beginning of 1907, and only one plaice caught in the present season's fishing belongs to last year's lot. We may conclude then that the stock of plaice appearing in the autumn in the Red Wharf Bay area of each year represents a new stock, and it is very probable that there are plaice which have migrated out from the shallow waters along the North Wales coast and from Menai Straits, since there are no indications from these marking experiments of a migration into this area from the shallow water nurseries on the Lancashire coast.

The results of this experiment indicate a great intensity of fishing on the coast of North Wales during the autumn and early winter. We know that this is the case apart altogether from the results of the marking experiments, and it appears from the returns of fish landed at Bangor that the present autumn and winter (1907) has been quite exceptional with regard to the amount of fishing in Red Wharf Bay and Channel Course. One would naturally conclude from the fact that over 30 per cent. of the plaice marked and liberated have been recaught within two months that the fishing had been very intense;

or it may be said that the percentage of these plaice recaught depends entirely on the amount of fishing being carried on in the neighbourhood of the place of liberation. But it is obvious that these two statements mean exactly the same thing.

#### INFLUENCE OF DIFFERENT METHODS OF FISHING.

Most of the marked fishes returned during 1907 were caught by 1st and 2nd class sailing trawlers. The following list is compiled from the tables of particulars of fishes returned:—

Caught by 1st class sailing trawlers ...	...	78
Do. 2nd class do. ...	...	36
Do. steam trawlers ...	...	10
Do. trammels, stake nets, "draw nets," &c.		15
Information not given, or doubtful ...	...	10

#### RATE OF GROWTH OF MARKED PLAICE.

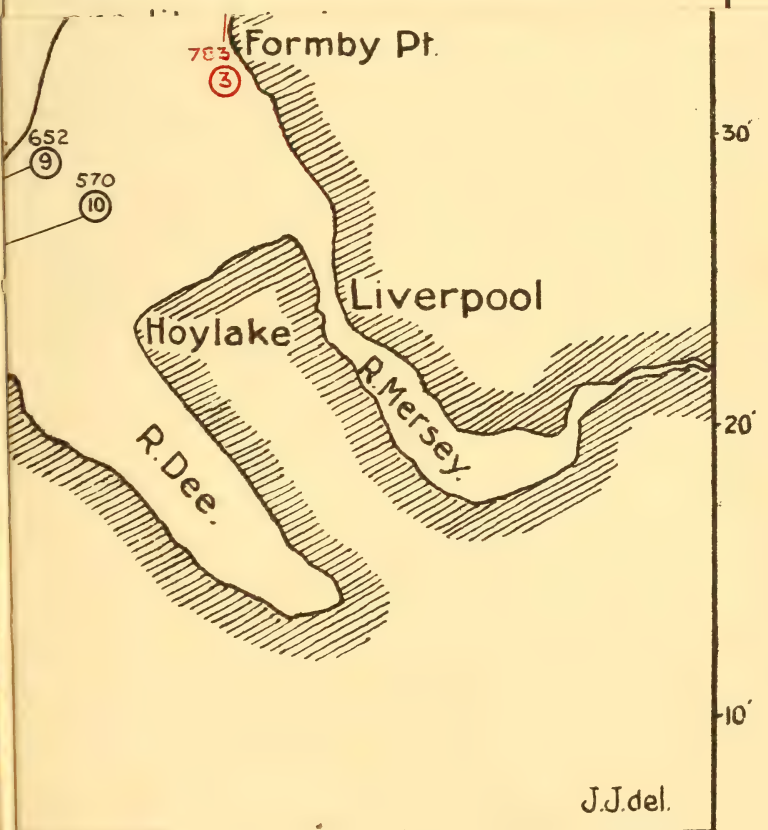
Only the results of Experiment 1 in 1907 can be utilised to deduce the variation in the rate of growth from month to month throughout the year. The numbers of fishes returned during the separate months were, however, small, and it does not appear useful to tabulate them here. I have examined the numbers, and the results are very much the same as those given in the last annual report, except that the increase in growth during the summer months does not appear to have been as rapid as is represented in the curve given in the last annual report. The numbers of fishes returned are, however, too small to justify any general conclusions as to a difference in the rate of growth between then and former years.

PLATE I.

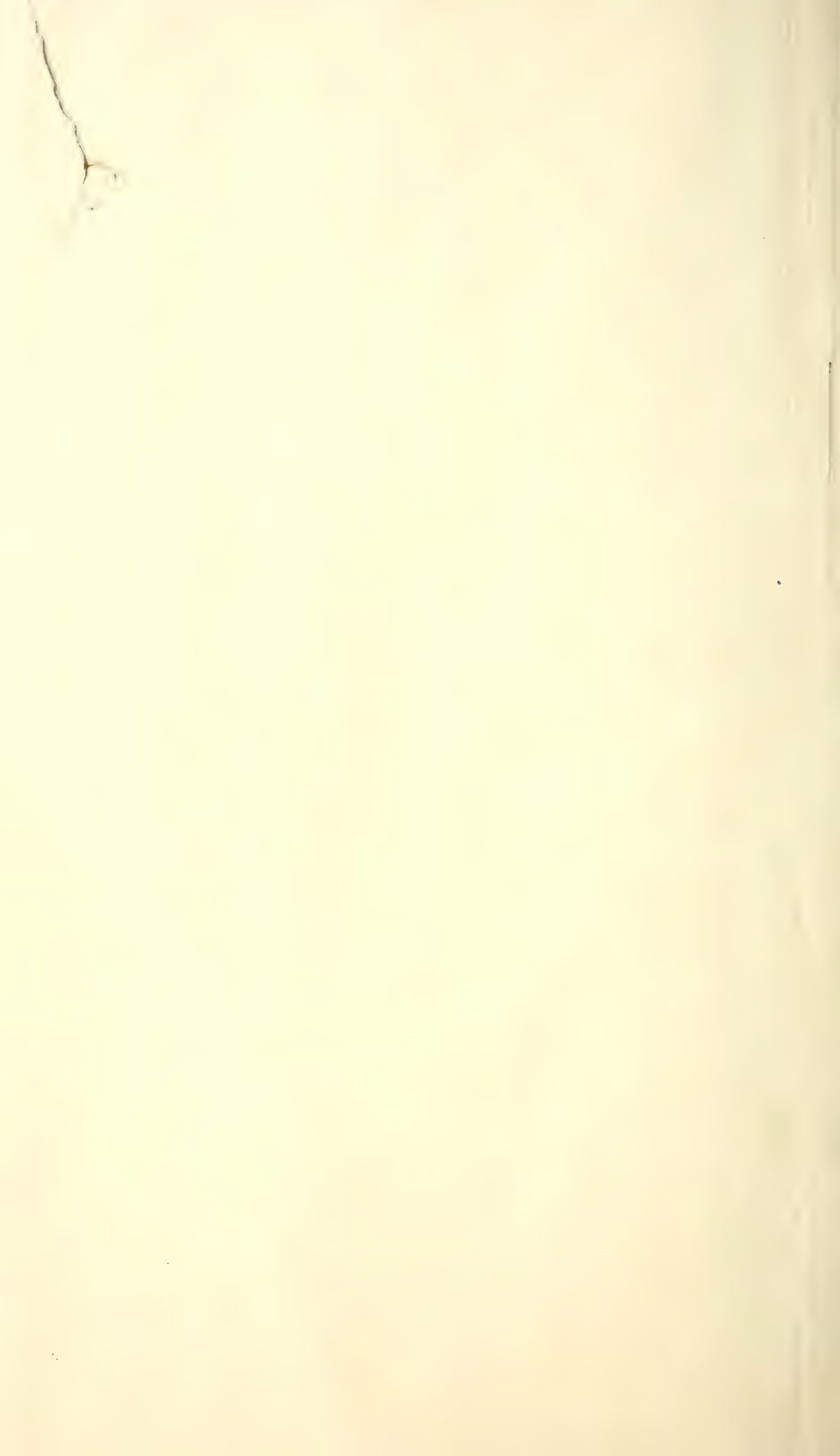
EXPERIMENT I (Black)

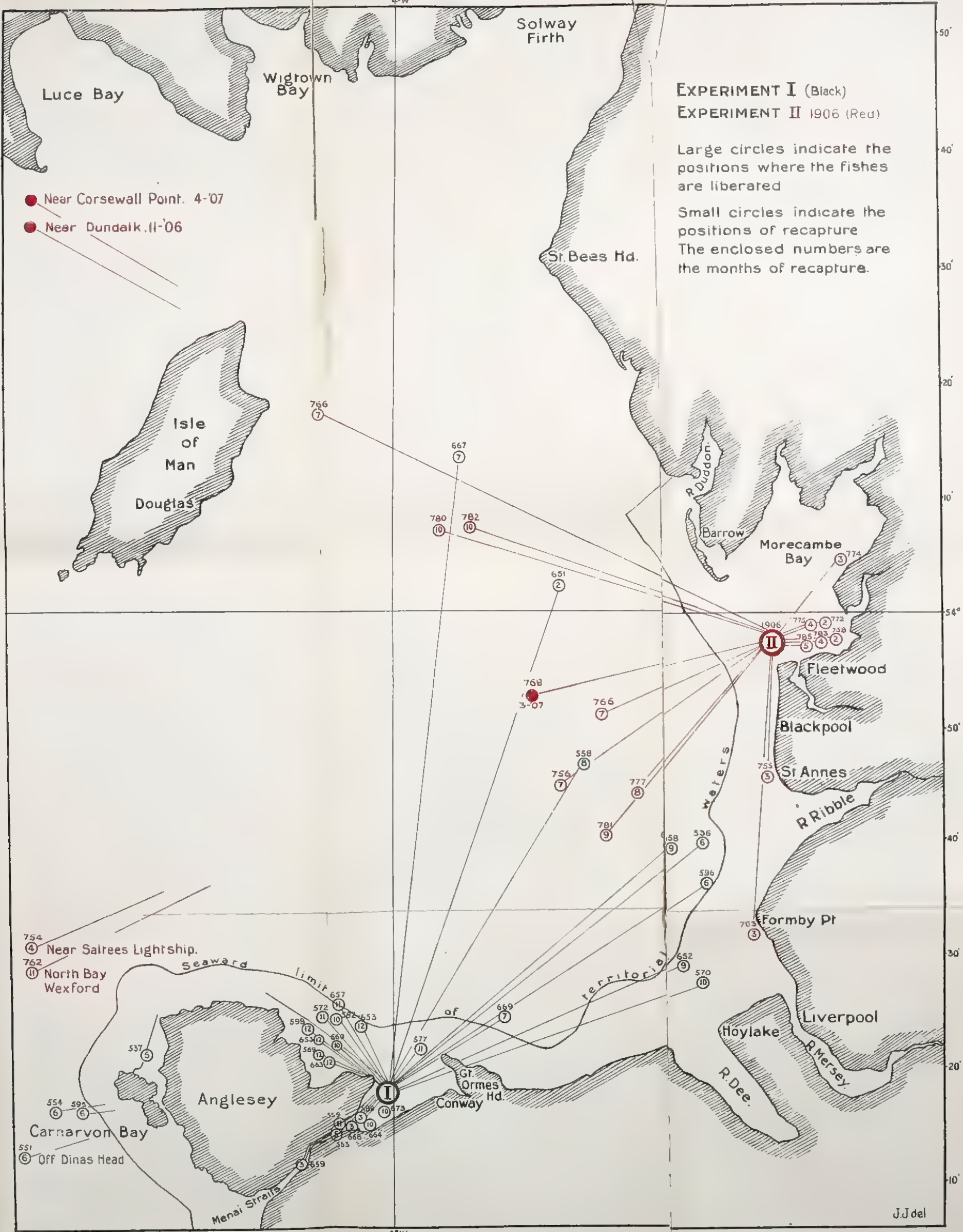
EXPERIMENT II 1906. (Red)

Large circles indicate the positions where the fishes







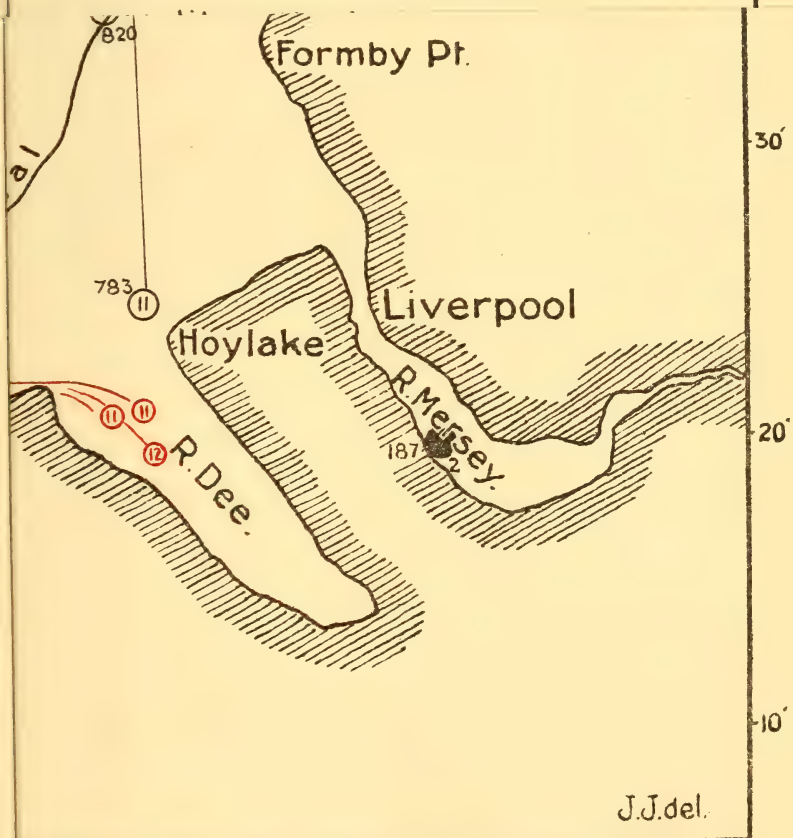




EXPERIMENT III (Black)

EXPERIMENT IV. (Red)

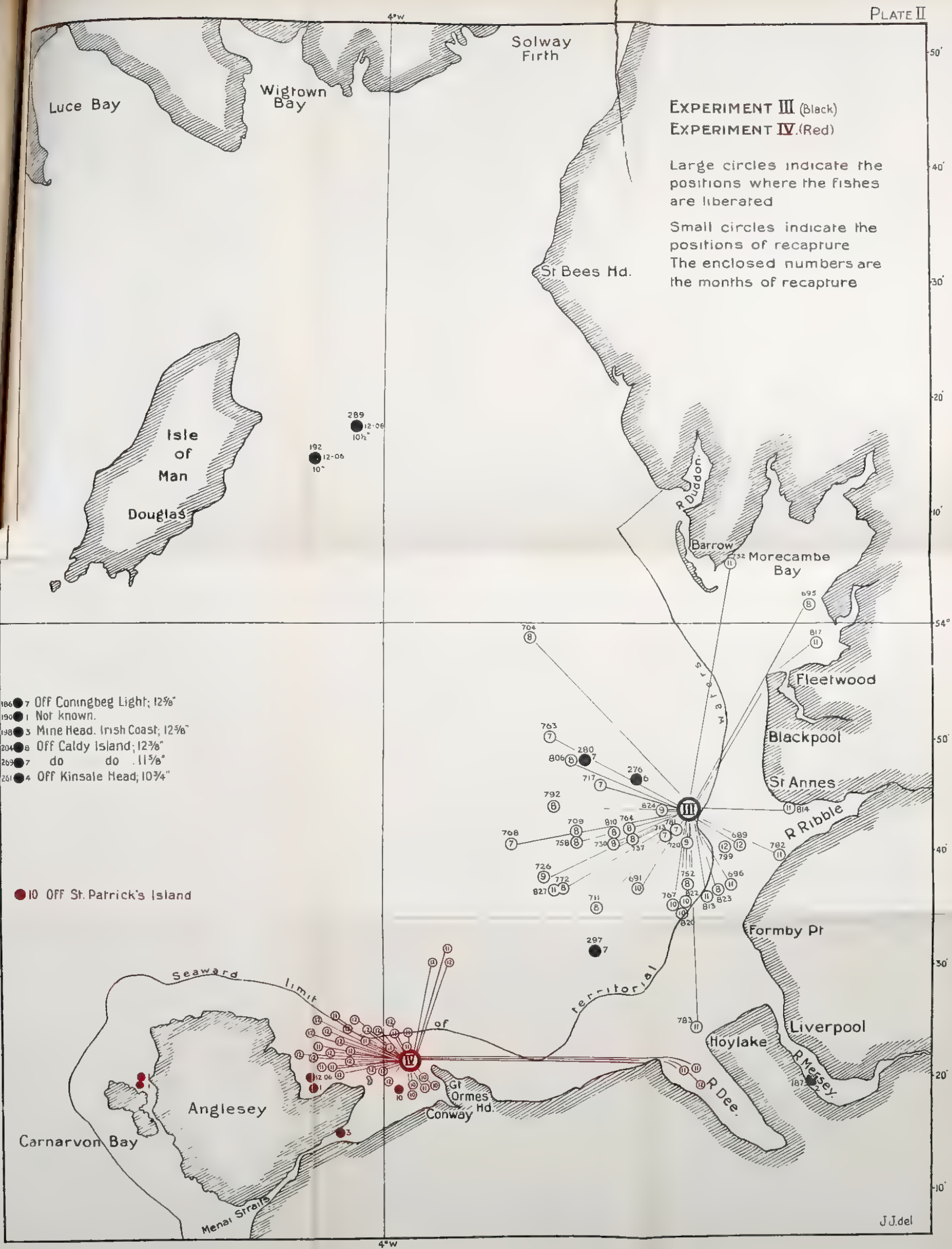
Large circles indicate the positions where the fishes



J.J.del.









## EXPLANATION OF THE CHARTS.

## Plate I.

Represents the results of Experiment 2, 1906, and Experiment 1, 1907. The small red circles indicate the approximate places of recapture of the plaice returned during 1906; the filled-in red circles indicate the positions of recapture of the plaice liberated in this experiment and recaptured during 1907. The numbers within the circles, or outside them in the cases of the 1907 recaptures, indicate the months in which the fishes were recaptured. The straight lines do not indicate migration paths, but relate the fish recaptured to their positions of liberation.

## Plate II.

Represents the results of Experiments 3 and 4, 1907. The open black circles relate to the plaice liberated off Nelson Buoy in July, 1907. The filled-in black circles indicate the approximate positions of recapture of plaice liberated near Nelson Buoy in 1906 and recaptured in 1907. The open red circles indicate the positions of recapture of the plaice liberated in Beaumaris Bay in October, 1907. The filled-in red circles indicate the recaptures of plaice liberated in Red Wharf Bay in September, 1906, and recaptured either at the end of last year or during 1907.

In both charts the numbers outside the circles are the numbers of the labels. To avoid confusion, however, these have been omitted in the case of Experiment 4.



RE-DESCRIPTION OF A TREMATODE PARASITE,  
*ALLOCREADIUM LABRACIS* (DUJARDIN),  
 FROM THE BASS.

(Plate III.)

By JAS. JOHNSTONE.

Bass or Sea-Perch (*Labrax* (or *Centropomus*) *lupus*) in the Irish Sea are nearly always infested with a Trematode parasite which is evidently the species *Allocreadium labracis* (Dujardin). This worm, if not of universal occurrence in the fish, is very common, and I have found it in specimens taken in Cardigan Bay, in the Irish Sea, and in Morecambe Bay. The bass is an inhabitant of the Mediterranean and the adjacent Atlantic coastal waters, where it is very abundant. It enters St. George's Channel and the Irish Sea in shoals in the early summer, and in June has reached Morecambe Bay, where there is nearly always a fishery for it during June, July and August. About September or October the shoals disappear. The fish appears to be largely a fish-eater, feeding upon young sand-eels and sprats which are abundant in Morecambe Bay during these months. Although common in the English Channel and the Irish Sea area, the shoals do not migrate much further north, and only isolated specimens are taken on the East Coast of Scotland, north of the Forth, and in Scandinavian waters. The parasite *Allocreadium labracis* appears to be a good example of a Trematode which has only one final host, as all the descriptions in the literature appear to relate to worms taken from the intestine of the bass. Thus Dujardin's original description of the species was based on a specimen taken from *Labrax lupus*, and Stossich and Molin described it from the same host.\* In such cases as this the occurrence of a

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\* The literature is summarised by Odhner in *Zool. Jahrb. Abth. System.*, Bd. 14, 1900-1. I am indebted to Mr. W. Nicol, of the Gatty Marine Laboratory, for directing my attention to this paper, and for other assistance.

parasite is often a useful indication of the places of origin of fishes with periodic migratory habits.

The following description of the trematode may be useful, since the species is not at all fully described in the literature. It is based on a reconstruction from a complete series of sections made from a worm of 9.7 mm. in total length, the largest found. The trematode was killed by immersion in fresh water, and was subsequently preserved in formalin, a procedure which enables one to preserve the worm with the minimum amount of distortion. But such a method is not favourable for the study of histological details, and I deal here only with the coarser anatomy of the parasite.

The measurements of the specimen are:—

Total length: 9.7 mm.

Greatest breadth: 2 mm.

Transverse diameter of oral sucker: 0.76 mm.

„ „ ventral sucker: 0.94 mm.

Diameters of ova: 0.079—0.095 by 0.048—0.064 mm.

Transverse diameter of oral sucker is contained 12 times in total body length.

Transverse diameter of ventral sucker is contained  $9\frac{1}{2}$  times in total body length.

Odhner's measurements vary slightly from those given above. Thus in his fig. 11, Taf. 33 (*op. cit.*) the body length is  $10\frac{1}{2}$  times the transverse diameter of the oral sucker, and  $6\frac{1}{2}$  times the transverse diameter of the ventral sucker. These ratios are not of precise diagnostic value; thus in a smaller specimen examined I found that the diameter of the oral sucker was contained about 10 times in the body length, and that of the ventral sucker about 7 times. Neither are the diameters of the ova very constant. Odhner gives these as 0.07—0.08 by 0.037.

The **body** is nearly cylindrical, and is only flattened dorso-ventrally at about the middle of the length. It is, as a rule, nearly uniform in diameter only tapering gently at either extremity. The skin possesses no spines or other form of armature.

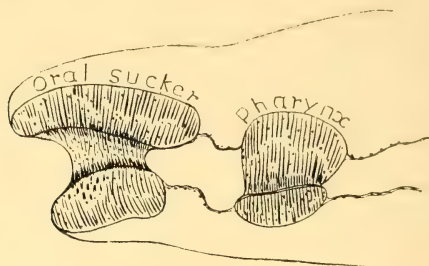


FIG. 1. *Allocreadium labracis* (Duj.). Median longitudinal section through mouth and pharynx.

The **mouth** is subterminal, as is indicated in fig. 1, which represents part of a median longitudinal section. Immediately following the oral sucker, and connected to it by a delicate tube is a strongly muscular, nearly globular **pharynx** of the usual type. The lumen of the pharynx is a longitudinal dorso-ventral slit, the inner surfaces of which are hard and fibrous. The pharynx passes immediately into a rather short oesophagus which, almost at once, bifurcates to form the two intestinal rami. The two branches of the intestine run roughly parallel to each other to almost the posterior extremity of the body. They have a nearly uniform diameter throughout. The lumen is not a simple one throughout. Round the periphery the wall is produced axially into the lumen as a loose vacuolated tissue, the central vacuoles being larger and continuous with each other, and this is the case as far back as the middle of the body. From thence backwards the vacuolated tissue in the intestine becomes

looser and finally disappears. The intestine is then a simple, thin-walled tube.

There is a very distinct **intestinal musculature**. From the posterior wall of the pharynx a series of strong muscle bundles take origin and pass backwards slightly obliquely to be inserted into the walls of the oesophagus just behind the pharynx. From here to the extremity of the intestinal branches these longitudinal muscles persist. They always appear in transverse sections of the body as little protuberances on the external surface of the intestine. They do not, however, form very long bundles, but are attached at intervals to the surface of the gut forming a series of short loops. They run quite longitudinally, and not at all obliquely. It is these longitudinal muscles which produce the peristaltic movements of the intestine. Circular muscle fibres are not to be seen in section, and are probably absent. But here and there the gut is attached to the lateral walls of the body by fibrous bundles, many of which appear to be muscular, and the contractions of these extrinsic intestinal muscles are probably antagonistic to those of the intrinsic longitudinal system.

The **ventral sucker** is situated rather nearer to the anterior, than to the posterior extremity. It is not quite round in shape; the longitudinal diameter is the larger in my specimens. The shape of the opening is, of course, variable, but is usually triangular. This sucker possesses a strong extrinsic musculature. All round its ventral periphery strong bundles of muscular and connective tissue take origin and run out radially to be inserted into the lateral and ventral body walls. Some run dorso-ventrally and are inserted into the dorsal body walls. These muscles, originating in the periphery of the ventral sucker, appear to constitute the principal system of



muscles in the body. There are also muscles which run dorso-ventrally, connecting together the dorsal and ventral body walls, and there are probably some longitudinally arranged muscles, though these latter are not very evident. When the animal dies the ventral sucker usually forms a prominent projection on the ventral surface, and the extremities are bent dorsally. This is probably due to the relaxation of the system of muscles surrounding the sucker, and to a contraction of longitudinal connective tissue fibres in the dorsal body wall.

The **genital aperture** is situated on the ventral surface in the middle line, and immediately behind the bifurcation of the intestine. It is not very evident in cleared preparations and can be recognised usually by the protruded cirrus. (Fig. 2.)

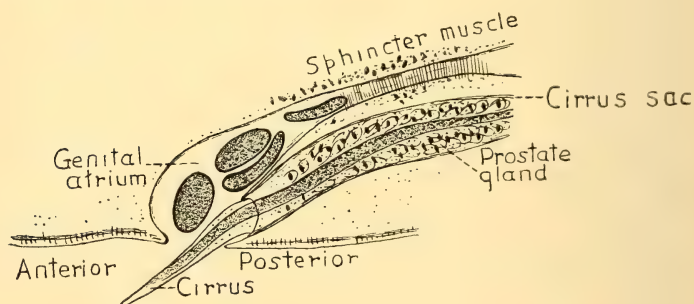


Fig. 2. *Allocreadium labracis* (Duj.). Part of median longitudinal section through genital cloaca.

### The Male Organs (Fig. 3).

There are two **testes**, nearly spherical in shape, but with rather irregular outlines, and nearly equal in size. They are situated nearly midway between the ventral sucker and the posterior extremity of the body. They lie one behind the other in the middle line. A **vas efferens** takes origin from each, one vessel from the

antero-dorsal surface of the posterior testis, and the other from the dorsal surface of the anterior organ. They run forward, pursuing an undulating course, penetrating between the convolutions of the uterus, and then dorsal to the ventral sucker. At the posterior margin of the latter they join together, entering at once into a capacious **seminal vesicle**.

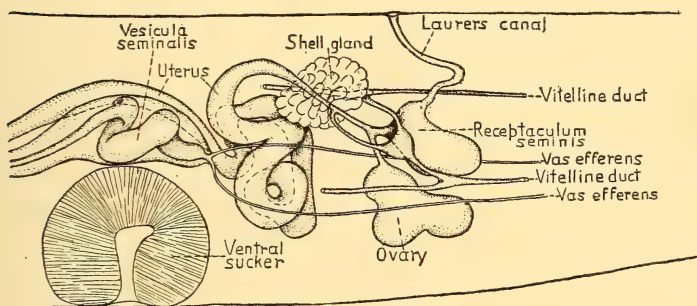


Fig. 3. *Allocreadium labracis* (Duj.). Diagram of genital ducts. Projection in vertical horizontal plane.

This latter structure is a wide tube situated dorsally to the ventral sucker. It is either a straight, or slightly bent vessel, as is shewn in fig. 3, or is thrown into two or three loose coils, as is indicated in Plate III, which is a projection in a longitudinal plane of the genital organs, and has been deduced from a series of longitudinal sections. The seminal vesicle is surrounded by a fairly thick fibrous and muscular sheath—the **cirrus-sheath**. At about the anterior margin of the ventral sucker the seminal vesicle contracts greatly in diameter to form the cirrus. But the cirrus-sheath is still wide, and the space between cirrus and sheath contains the follicles of the **prostate gland**. The cirrus itself is a narrow, thick-walled tube, and it is quite unarmed. The cirrus-sheath or pouch terminates in the ventral and posterior part of

the genital cloaca, and in preserved specimens the cirrus usually protrudes from the opening of the former.

**The Female Organs** (Pl. III and fig. 3).

The **ovary** is rather small, and is situated on the right side between the ventral sucker and anterior testis. It is trilobate in shape in the published descriptions of the species, but in my specimens there are always three equal-sized, rounded lobes in a horizontal plane, and dorsal to these, and nearly over the anterior lobe, another from which a short, thin duct takes origin. Immediately dorsal to the ovary, and usually obscured by the latter in cleared preparations, is a capacious **receptaculum seminis**. The little duct leaving the ovary joins the former at its anterior border. There is a projection of the receptaculum seminis on its dorsal and anterior part, and from this a fairly wide and thick-walled duct—**Laurer's canal**—takes origin, runs at first backward and upward forming a prominent bend, and then passes obliquely forward to open on the dorsal surface of the body and nearly in the middle line. Laurer's canal was empty in my specimens. The receptaculum seminis contained granular matter, the nature of which could not be determined: it was probably broken down spermatozoa.

Just where the duct from the ovary joins the receptaculum seminis the **ootype** takes origin. This is a very narrow tube which runs at first directly forward, through a mass of loose gland follicles, which together form the **shell-gland**. Emerging from the latter (which, of course, opens into it) the ootype enlarges greatly to form the **uterus**, and the latter is thrown into a series of close convolutions filling up most of the space between ovary and receptaculum seminis behind, and ventral sucker forward. The uterus is not nearly so capacious as in many other trematodes. Its general appearance and

distribution is represented in Pl. III. In fig. 3 the convolutions are represented diagrammatically to secure clearness. For the same reason the eggs have been omitted in both figures. The uterus passes forward over the ventral sucker, at first side by side, and then dorsal to, the seminal vesicle. It contracts greatly in diameter in the neighbourhood of the latter structure. Here, and here only, the uterus is muscular. Just over the prostate gland there is a sphincter muscle (fig. 2), the contraction of which usually reduces the calibre of the uterus to much less than the diameter of an ovum. In fig. 2 this sphincter is represented as a long-drawn-out structure, but in other sections I have seen it as a short, thick, flat ring of muscle fibres. This indicates that there are probably also longitudinal muscle fibres present, though it is difficult to see these. The structure functions doubtless in the extrusion of the ova.

Immediately in front of this sphincter muscle the calibre of the uterus enlarges, and we have a fairly wide chamber which is the genital cloaca (fig. 2). In this, as the figure shows, there are usually a few eggs. The opening on the surface of the body is circular. Into the terminal part of the genital cloaca there opens the cirrus pouch, and usually the cirrus itself protrudes from the latter, and out from the genital aperture on to the surface of the body.

The **vitellaria** are very characteristic. In a cleared preparation they appear to ramify over every part of the body, obscuring most of the other organs. This is particularly the case at the posterior extremity, where the vitelline glands appear to fill up the whole body. But in section they are seen to be arranged peripherally, generally as a single stratum of gland follicles. At the middle of the body they are dorsal and lateral. In front



of the ventral sucker they are present only beneath the dorsal body wall. In the region of the testes they are lateral (fig. 4) and do not appear on dorsal and ventral surfaces. Behind the testes they are distributed round the entire periphery of the body. They are very numerous, and when the worm is contracted greatly appear very closely packed together, so that it is almost impossible to make out the other organs. Indeed it is only by killing the trematode in fresh water, and then by flattening it out between two microscope slides during fixation, that the animal can be preserved in a condition fit for staining and clearing.

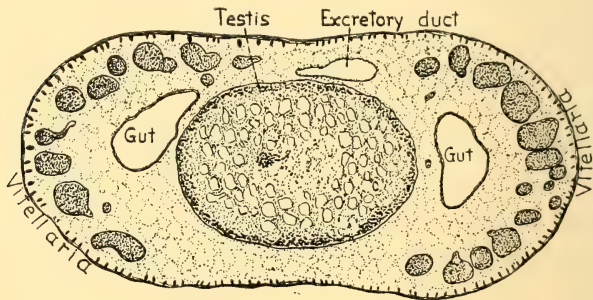
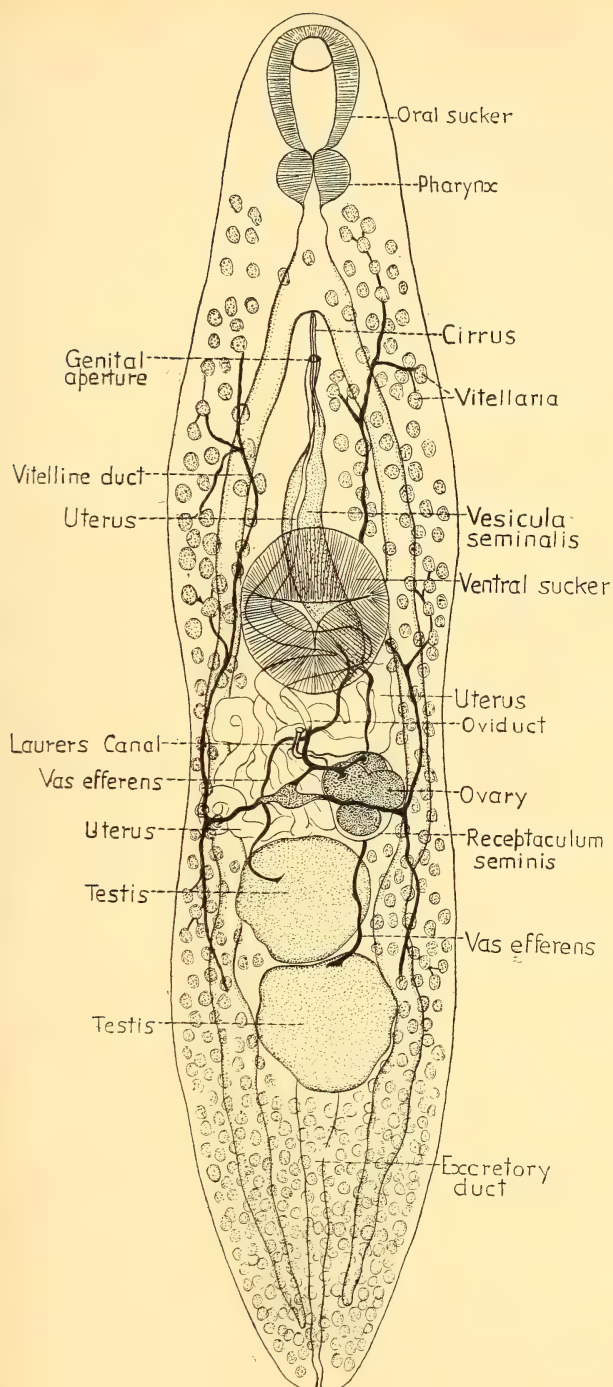


Fig. 4. *Allocreadium labracis* (Duj.). Transverse section through posterior testis.

The **vitelline ducts** have the usual disposition. It is not difficult to trace most of their ramifications in a successful preparation. One main longitudinal duct runs along either side of the body, and to this numerous ductules proceed from the follicles of the gland. At about the transverse level of the ovary fairly wide transverse ducts appear, and these run across towards the middle line, uniting to form a rather large vesicle, which is, of course, only an enlargement of the united ducts. From this vesicle a slender efferent duct takes origin, and runs



*Allocreadium labracis* (Dujardin). Dorsal aspect.  
Reconstructed from serial sections mag. =  $\times 18$ .



obliquely forward to pass into the midst of the follicles of the shell gland. It is difficult to trace in section, but can be seen to open into the ootype as the latter passes through the shell-gland.

The **excretory system** cannot be traced in sections. There is one main vessel which opens to the surface at the very posterior tip of the body. It is elongated dorso-ventrally. It can easily be traced in section as far forward as the testes, and here it is lost. Doubtless it breaks up in the characteristic manner into a multitude of smaller vessels, but I could see no indication of the usual two lateral excretory vessels uniting in the region of the oral sucker. But it is always much easier to trace the excretory system in the living worm, and I had no opportunity of examining such specimens.

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### PLATE III.

*Allocreadium labracis* (Dujardin).

Reconstructed from a series of transverse sections.  
Magnified about 18 diameters.



REPORT ON THE HYDROGRAPHIC WORK IN THE  
EASTERN PORTION OF THE IRISH SEA BETWEEN  
JULY, 1906, AND NOVEMBER, 1907.

By HENRY BASSETT, Jun., B.Sc., Ph.D., Demonstrator and  
Assistant Lecturer in Chemistry in the University  
of Liverpool.

The seas surrounding the British Isles are filled with only slightly diluted Atlantic water.

Speaking generally, the water filling the Irish Sea is a good deal more dilute than that in the English Channel and the North Sea, and, owing to the tidal current which runs from South to North through the Irish Sea and round the North Coast of Scotland, the water from the Irish Sea plays a very important part in the dilution of the Atlantic water which goes to fill the North Sea.

The Irish Sea is plainly so dilute because of the large volumes of fresh water flowing into it from the land.

Now a very large proportion indeed of the fresh water running into the Irish Sea runs into that portion of it which is situated to the East of a line drawn from Burrow Head, in Wigtownshire, due South to Anglesey; for most of the drainage from the parts of England and North Wales having the largest rainfall passes into this portion. This part of the Irish Sea is also remarkable for its strong tides, and these, owing to the peculiar conformation of the coast line, and the position of the Isle of Man, cause a very thorough mixing of the waters, and ensure the efficient dilution of any salter water coming in from the South.

A study of the salinity of this portion of the Irish Sea promised, therefore, to be of considerable interest.

For some years past temperature and salinity measurements at various depths have been made in the Western portion of the Irish Sea by the Irish Board of Agriculture and Technical Instruction, under the direction of Mr. E. W. L. Holt; but up to 1906 the Eastern portion had been left almost entirely alone. From 1904 onwards the "*Bulletins trimestriels du Conseil permanent international pour l'exploration de la mer*" give the results of salinity and temperature observations made on surface samples collected by the Bahama Bank ( $54^{\circ} 19' N$ ;  $40^{\circ} 13' E$ ) and Cardigan Bay ( $52^{\circ} 24' N$ ;  $5^{\circ} 00' E$ ) lightships. From this information surface isohalines are drawn in the published charts.

In July, 1906, a systematic study of the Eastern portion of the Irish Sea was begun under the scheme of hydrographic observations sanctioned by the Lancashire and Western Sea-Fisheries Committee. On the first voyage samples were collected from points situated on lines drawn from Piel Gas Buoy to Maughold Head, and from the Calf of Man to Holyhead breakwater. A few samples from other positions were also collected on this trip. These two lines were kept to until the end of 1906, during which interval of time two more trips were made.

For the next two trips (February and May, 1907) the first line of soundings was altered to one running W.N.W. from Piel Gas Buoy instead of N.W. The other line remained as before.

Finally, in July, 1907, the first line underwent a slight alteration so as to make it run along the  $54^{\circ}$  of latitude and to bring it into agreement with the line of soundings run out from the Irish Coast to the Calf of

Man by Mr. Holt. The line from the Calf of Man to Holyhead still remained as before.

In May, 1907, the area under investigation was extended somewhat, an additional line of soundings being run across Carnarvon and Cardigan Bays.

The water samples, except those from the surface, have always been collected by means of a Nansen-Pettersson water-bottle, while the temperatures have been taken with the usual pattern of thermometer used in the International Fishery Investigations. The titrations of the water samples have been carried out in the usual way by Mohr's method,\* and the salinities, etc. calculated by means of Knudsen's Hydrographic tables. The titrations have all been done by myself, but I have only occasionally been able to go out on the steamer collecting the samples. The latter have usually been obtained by my colleague, Mr. James Johnstone, whom I have much pleasure in thanking for this and much other assistance.

My thanks are also due to Captain A. Wignall, of the "John Fell," the steamer of the Lancashire and Western Sea-Fisheries Committee, from which all the observations have been made, for the skill with which he has fixed the positions of the soundings.

The salinities and other details for the various stations are given in the following tables. The first column gives the depth in metres;  $T^{\circ}$  is the temperature (Centigrade) of the water *in situ*;  $Cl\text{‰}$  is the amount of chlorine per 1000 parts of water as found by the titration;  $S\text{‰}$  is the salinity; and  $1 + \frac{\sigma_t}{1000}$  gives the density of the sample of water at the temperature  $T^{\circ}$ . The position of the station and the date on which the samples were collected are given above each table.

\*For details of the method as applied to hydrographic work, see Niels Bjerrum, Meddelelser fra Kommissionen for Havundersogelser. Serie: Hydrografi. Vol. I, No. 3.—Copenhagen, 1904.

July 2 to 5, 1906.

The positions on the two chief lines are given first.

5/7/06. 54° 4' N.; 3° 23' W. Depth of station, 22 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	14.15	18.18	32.84	24.52
9.2	13.5	18.16	32.81	24.64
18.3	13.5	18.16	32.81	24.64

5/7/06. 54° 7' N.; 3° 37' W. Depth of station, 30.2 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15.96	18.14	32.77	24.08
9.2	13.5	18.15	32.79	24.62
18.3	12.2	18.36	33.17	25.14
27.5	11.9	18.39	33.22	25.26

5/7/06. 54° 11' N.; 3° 51' W. Depth of station, 27.5 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15.55	18.14	32.77	24.18
9.2	12.80	18.29	33.04	24.95
18.3	12.30	18.46	33.35	25.28
25.6	12.25	18.46	33.35	25.29

5/7/06. 54° 14' N.; 4° 3' W. Depth of station, 27.5 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	14.6	18.44	33.31	24.77
9.2	12.6	18.52	33.46	25.28
23.8	12.3	18.54	33.49	25.38



3/7/06. 53° 55' N.; 4° 56' W. Depth of station, 76·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·46	18·93	34·24	25·89
9·2	12·15	18·90	34·14	25·90
18·3	12·15	18·92	34·18	25·93
36·6	11·45	18·92	34·18	26·07
54·9	9·97	18·94	34·22	26·36
73·2	9·55	18·94	34·22	26·42

3/7/06. 53° 49' N.; 4° 46' W. Depth of station, 53·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·19	18·91	34·16	26·10
9·2	11·02	18·90	34·14	26·14
18·3	11·02	18·90	34·14	26·14
36·6	11·00	18·91	34·16	26·15
51·3	11·00	18·90	34·14	26·14

3/7/06. 53° 37' N.; 4° 42' W. Depth of station, 54·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·72	18·89	34·13	25·97
9·2	11·00	18·90	34·14	26·14
18·3	11·00	18·89	34·13	26·12
36·6	11·00	18·90	34·14	26·14
54·9	11·00	18·90	34·14	26·14

3/7/06. 53° 29' N.; 4° 40' W. Depth of station, 64·1 metres.

Depth (metres)	T°	Cl °/∞	S °/∞	$\sigma_t$
0	11·80	18·85	34·05	25·90
9·2	11·62	18·82	34·00	25·88
18·3	11·60	18·82	34·00	25·88
36·6	11·60	18·83	34·02	25·90
54·9	11·55	18·86	34·07	25·94

3/7/06. 53° 24' N.; 4° 39' W.

Depth (metres)	T°	Cl °/∞	S °/∞	$\sigma_t$
0	11·65	18·87	34·09	25·95

Samples were only collected from the following stations on this one trip.

2/7/06. 53° 26' N.; 4° 26' W.

Depth (metres)	T°	Cl °/∞	S °/∞	$\sigma_t$
27·5	12·20	18·75	33·87	25·70

3/7/06. 54° 22' N.; 4° 34' W.

Depth (metres)	T°	Cl °/∞	S °/∞	$\sigma_t$
0	12·10	18·89	34·13	25·90

3/7/06. 54° 25' N.; 4° 21' W. Depth of station, 23·8 metres.

Depth (metres)	T°	Cl °/∞	S °/∞	$\sigma_t$
0	12·45	18·78	33·93	25·68
9·2	12·00	18·78	33·93	25·78
18·3	12·00	18·76	33·89	25·75

3/7/06.  $54^{\circ} 22' N.$ ;  $4^{\circ} 19' W.$  Depth of station, 31.1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12.95	18.58	33.57	25.31
9.2	12.30	18.56	33.53	25.41
18.3	12.23	18.57	33.55	25.44
27.5	12.23	18.58	33.57	25.45

3/7/06.  $54^{\circ} 22' N.$ ;  $4^{\circ} 2' W.$  Depth of station, 40.3 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	14.1	18.29	33.04	24.69
9.2	12.70	18.31	33.08	24.98
18.3	12.60	18.32	33.10	25.01
36.6	11.35	18.46	33.35	25.45

5/7/06.  $54^{\circ} 0' N.$ ;  $3^{\circ} 13' W.$

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	17.00	17.53	31.67	23.00

5/7/06.  $54^{\circ} 3' N.$ ;  $3^{\circ} 10' W.$

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15.90	18.09	32.68	24.01

5/7/06.  $53^{\circ} 58' N.$ ;  $3^{\circ} 9' W.$

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	16.00	17.64	31.87	23.37

Surface samples collected on July 9 and 10, 1906.

Position.	T°	Cl ‰	S ‰	$\sigma_t$
53° 19' N. ; 4° 43' W.	12·9	18·88	34·11	25·75
53° 10' N. ; 4° 43' W.	12·2	18·95	34·23	25·98
53° 1' N. ; 4° 44' W.	11·4	19·03	34·38	26·25
52° 52' N. ; 4° 45' W.	11·9	19·02	34·36	26·14
52° 47' N. ; 4° 43' W.	12·9	18·89	34·13	25·76
52° 26' N. ; 4° 34' W.	13·5	18·86	34·07	25·61
52° 18' N. ; 4° 27' W.	14·8	18·82	34·00	25·27
52° 13' N. ; 4° 24' W.	15·0	18·69	33·77	25·04

September 18 and September 19, 1906.

18/9/06. 54° 3' N. ; 3° 22' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15·20	18·25	32·97	24·40
9·2	13·50	18·26	32·99	24·77
22·0	13·50	18·24	32·95	24·74

18/9/06. 54° 7' N. ; 3° 36' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15·00	18·38	33·21	24·63
9·2	14·00	18·37	33·19	24·83
18·3	14·00	18·51	33·44	25·02
27·5	14·00	18·53	33·48	25·04

18/9/06. 54° 10' N. ; 3° 50' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15·2	18·44	33·31	24·67
9·2	14·0	18·46	33·35	24·94
18·3	14·0	18·47	33·37	24·95
27·5	14·0	18·47	33·37	24·95



18/9/06. 54° 14' N.; 4° 2' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15.0	18.52	33.46	24.81
9.2	14.0	18.52	33.46	25.01
18.3	14.0	18.52	33.46	25.01
27.5	14.0	18.52	33.46	25.01

19/9/06. 53° 56' N.; 4° 47' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	13.7	18.84	34.04	25.54
9.2	13.0	18.85	34.05	25.68
18.3	13.0	18.84	34.04	25.67
36.6	13.0	18.84	34.04	25.67
53.1	13.0	18.84	34.04	25.67

19/9/06. 53° 47' N.; 4° 45' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	13.7	18.89	34.13	25.60
9.2	13.5	18.88	34.11	25.63
18.3	13.2	18.88	34.11	25.69
36.6	13.2	18.88	34.11	25.69
58.6	13.2	18.88	34.11	25.69

19/9/06. 53° 38' N.; 4° 43' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	13.8	18.89	34.13	25.60
18.3	13.5	18.90	34.14	25.66
36.6	13.5	18.88	34.11	25.63
54.9	13.5	18.89	34.13	25.65
69.5	13.2	18.88	34.11	25.69

19/9/06. 53° 28' N.; 4° 40' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	14·7	18·84	34·04	25·34
9·2	13·8	18·82	34·00	25·49
18·3	13·8	18·84	34·04	25·54
36·6	13·5	18·83	34·02	25·57
64·1	13·5	18·83	34·02	25·57

November 13—November 14, 1906.

13/11/06. 54° 3' N.; 3° 22' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·0	18·49	33·40	25·56
9·2	11·0	18·49	33·40	25·56
25·7	11·0	18·49	33·40	25·56

13/11/06. 54° 7' N.; 3° 36' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·1	18·62	33·64	25·72
9·2	11·3	18·62	33·64	25·68
27·5	11·3	18·65	33·69	25·72

13/11/06. 54° 10' N.; 3° 50' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·1	18·30	33·06	25·27
9·2	10·7	18·28	33·03	25·30
26·5	10·7	18·29	33·04	25·31

13/11/06.    54° 14' N.; 4° 2' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	10·6	18·29	33·04	25·33
9·2	10·6	18·30	33·06	25·34
22·0	10·6	18·25	32·97	25·27

14/11/06.    53° 56' N.; 4° 47' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·3	18·78	33·93	25·90
9·2	11·1	18·74	33·86	25·88
27·5	11·1	18·75	33·87	25·90
45·8	11·1	18·75	33·87	25·90

14/11/06.    53° 47' N.; 4° 45' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·8	18·83	34·02	25·89
9·2	11·6	18·84	34·04	25·93
36·6	11·6	18·82	34·00	25·90
64·1	11·6	18·82	34·00	25·90

14/11/06.    53° 38' N.; 4° 43' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·0	18·84	34·04	25·86
9·2	11·9	18·83	34·02	25·87
45·8	12·0	18·84	34·04	25·86

February 13—February 18, 1907.

13/2/07 (10-40 a.m.) 54° 1' N.; 3° 30' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	3·6	17·88	32·30	25·71
18·3	3·5	17·89	32·32	25·74
27·5	3·5	17·89	32·32	25·74

13/2/07 (11-50 a.m.) 54° 2' N.; 3° 47' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	4·6	18·22	32·92	26·08
18·3	3·4	18·21	32·90	26·19
36·6	3·5	18·22	32·92	26·19

13/2/07 (1-0 p.m.) 54° 2' N.; 4° 4' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	5·9	18·40	33·24	26·22
18·3	5·3	18·37	33·19	26·23
27·5	5·3	18·38	33·21	26·24

13/2/07 (2-10 p.m.) 54° 3' N.; 4° 20' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	5·65	18·54	33·49	26·44
18·3	5·6	18·54	33·49	26·44
34·8	5·6	18·53	33·48	26·43

18/2/07 (1-0 p.m.) 53° 53' N.; 4° 46' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	7·3	19·04	34·40	26·93
18·3	6·9	19·03	34·38	26·97
36·6	6·9	19·03	34·38	26·97
54·9	6·9	19·03	34·38	26·97



18/2/07 (11-55 a.m.)    53° 43' N.; 4° 44' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	7.2	19.00	34.33	26.89
18.3	6.9	18.98	34.29	26.90
36.6	6.9	18.99	34.31	26.92
54.9	6.9	18.99	34.31	26.92

18/2/07 (10-45 a.m.)    53° 33' N.; 4° 41' W.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	6.7	18.68	33.75	26.49
18.3	6.5	18.69	33.77	26.54
36.6	6.5	18.69	33.77	26.54
54.9	6.5	18.72	33.82	26.59

May 6—May 8, 1907.

6/5/07 (8-50 a.m.)    54° 1' N.; 3° 31' W.    Depth of station, 28 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	7.95	18.02	32.56	25.39
9.2	7.8	18.03	32.57	25.43
18.3	7.7	18.07	32.65	25.49
27.5	7.65	18.19	32.86	25.66

6/5/07 (10 a.m.)    54° 2' N.; 3° 47' W.    Depth of station, 40.3 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	8.2	18.50	33.42	26.03
9.2	7.75	18.48	33.39	26.07
18.3	7.7	18.50	33.42	26.10
36.6	7.8	18.57	33.55	26.20

6/5/07 (11 a.m.) 54° 2' N.; 4° 4' W. Depth of station, 38·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	8·4	18·63	33·66	26·18
9·2	7·75	18·64	33·68	26·30
18·3	7·8	18·63	33·66	26·28
36·6	7·7	18·68	33·75	26·36

6/5/07 (noon). 54° 3' N.; 4° 20' W. Depth of station, 42·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	8·1	18·96	34·25	26·69
9·2	7·85	18·97	34·27	26·75
18·3	7·85	18·97	34·27	26·75
36·6	7·8	18·96	34·25	26·73

7/5/07 (8-40 a.m.) 53° 53' N.; 4° 46' W. Depth of station, 64·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	7·8	19·00	34·33	26·79
9·2	7·5	19·02	34·36	26·87
18·3	7·6	19·04	34·40	26·90
36·6	7·6	19·05	34·42	26·91
60·4	7·6	19·05	34·42	26·91

7/5/07 (10 a.m.) 53° 43' N.; 4° 44' W. Depth of station, 64·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	7·95	18·98	34·29	26·74
9·2	7·75	18·97	34·27	26·78
18·3	7·75	18·99	34·31	26·81
36·6	7·7	18·98	34·29	26·79
60·4	7·7	19·00	34·33	26·82

7/5/07 (11-25 a.m.) 53° 33' N.; 4° 41' W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	8·1	18·80	33·96	26·45
9·2	8·0	18·78	33·93	26·46
18·3	8·0	18·78	33·93	26·46
36·6	8·0	18·79	33·95	26·48
54·9	8·0	18·79	33·95	26·48

7/5/07 (2-25 p.m.) 53° 5' N.; 4° 44' W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	8·3	18·95	34·23	26·65
9·2	8·1	18·95	34·23	26·69
18·3	7·95	18·96	34·25	26·71
36·6	7·9	18·94	34·22	26·69
54·9	7·9	18·94	34·22	26·69

8/5/07 (9-15 a.m.) 52° 34' N.; 4° 45' W. Depth of station, 43·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	8·7	18·84	34·04	26·44
9·2	8·4	18·84	34·04	26·49
18·3	8·4	18·84	34·04	26·49
36·6	8·4	18·84	34·04	26·49

8/5/07 (10-30 a.m.) 52° 24' N.; 4° 43' W. Depth of station, 40·3 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	8·8	18·81	33·98	26·38
9·2	8·7	18·81	33·98	26·39
18·3	8·65	18·81	33·98	26·39
36·6	8·6	18·81	33·98	26·40

July 29—July 30, 1907.

29/7/07 (8-30 a.m.) 54° N.; 3° 30' W. Depth of station, 27·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	15·8	17·64	31·87	23·42
9·2	13·5	17·76	32·09	24·07
18·3	13·0	18·11	32·72	24·66
27·5	13·0	18·13	32·75	24·69

29/7/07 (9-50 a.m.) 54° N.; 3° 47' W. Depth of station, 36·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	13·0	18·67	33·73	26·43
9·2	12·8	18·71	33·80	26·54
18·3	12·8	18·72	33·82	26·56
36·6	12·8	18·71	33·80	26·54

29/7/07 (11-10 a.m.) 54° N.; 4° 4' W. Depth of station, 36·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	13·0	18·85	34·05	26·68
9·2	12·5	18·85	34·05	26·78
18·3	12·5	18·85	34·05	26·78
36·6	12·6	18·85	34·05	26·76

29/7/07 (12-30 p.m.) 54° N.; 4° 20' W. Depth of station, 45·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·6	18·88	34·11	25·81
18·3	12·3	18·88	34·11	25·87
36·6	12·3	18·87	34·09	25·85
45·8	12·3	18·87	34·09	25·85



29/7/07 (3 p.m.) 53° 53' N.; 4° 46' W. Depth of station, 73·2 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·3	18·89	34·13	25·88
18·3	12·1	18·88	34·11	25·90
36·6	12·0	18·88	34·11	25·92
64·1	11·9	18·87	34·09	25·92

29/7/07 (4-25 p.m.) 53° 43' N.; 4° 44' W. Depth of station, 54·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·1	18·87	34·09	25·88
18·3	11·9	18·87	34·09	25·92
36·6	11·9	18·87	34·09	25·92
53·1	11·9	18·87	34·09	25·92

29/7/07 (5-45 p.m.) 53° 33' N.; 4° 41' W. Depth of station, 54·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·9	18·81	33·98	25·66
18·3	12·7	18·80	33·96	25·68
36·6	12·7	18·80	33·96	25·68
53·1	12·7	18·80	33·96	25·68

29/7/07 (8-45 p.m.) 53° 5' N.; 4° 44' W. Depth of station, 64·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	13·25	18·84	34·04	25·63
18·3	12·8	18·86	34·07	25·75
36·6	12·5	18·87	34·09	25·82
54·9	12·5	18·87	34·09	25·82

30/7/07 (8 a.m.) 52° 34' N.; 4° 45' W. Depth of station, 36·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·9	18·85	34·05	25·90
9·2	11·8	18·85	34·05	25·92
18·3	11·6	18·86	34·07	25·98
36·6	11·6	18·85	34·05	25·96

30/7/07 (9-25 a.m.) 52° 24' N.; 4° 43' W. Depth of station, 36·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	14·0	18·78	33·93	25·38
9·2	13·25	18·77	33·91	25·53
18·3	13·25	18·78	33·93	25·54
36·6	13·25	18·78	33·93	25·54

November 4—November 6, 1907.

4/11/07 (11-5 a.m.) 54° N.; 3° 30' W. Depth of station, 29·3 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·5	18·32	33·10	25·23
9·2	11·55	18·37	33·19	25·31
18·3	11·7	18·44	33·31	25·38
27·5	11·7	18·45	33·33	25·39

4/11/07 (12-15 p.m.) 54° N.; 3° 47' W. Depth of station, 39·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·9	18·62	33·64	25·58
9·2	11·8	18·63	33·66	25·61
18·3	11·8	18·63	33·66	25·61
36·6	11·8	18·63	33·66	25·61

4/11/07 (1-24 p.m.)      54° N.; 4° 4' W.      Depth of station, 42·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·8	18·75	33·87	25·78
9·2	11·75	18·74	33·86	25·77
18·3	11·7	18·75	33·87	25·80
36·6	11·8	18·75	33·87	25·78

4/11/07 (2-30 p.m.)      54° N.; 4° 20' W.      Depth of station, 46·7 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	11·8	18·76	33·89	25·79
9·2	11·75	18·75	33·87	25·78
18·3	11·75	18·75	33·87	25·78
40·3	11·75	18·75	33·87	25·78

5/11/07 (10 a.m.)      53° 53' N.; 4° 46' W.      Depth of station, 87·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·45	18·82	34·00	25·75
18·3	12·6	18·82	34·00	25·73
36·6	12·4	18·80	33·96	25·74
54·9	12·4	18·80	33·96	25·74
82·4	12·4	18·82	34·00	25·77

5/11/07 (11-25 a.m.)      53° 43' N.; 4° 44' W.      Depth of station, 64·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·7	18·79	33·95	25·67
18·3	12·7	18·79	33·95	25·67
36·6	12·6	18·79	33·95	25·69
54·9	12·6	18·78	33·93	25·67

5/11/07 (12-35 p.m.) 53° 33' N.; 4° 41' W. Depth of station, 64·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·4	18·67	33·73	25·55
18·3	12·3	18·67	33·73	25·57
36·6	12·4	18·67	33·73	25·55
54·9	12·4	18·67	33·73	25·55

6/11/07 (11-30 a.m.) 53° 5' N.; 4° 44' W. Depth of station, 64·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·6	19·16	34·61	26·21
18·3	12·5	19·15	34·60	26·21
36·6	12·5	19·15	34·60	26·21
50·3	12·5	19·15	34·60	26·21

6/11/07 (2-30 p.m.) 52° 34' N.; 4° 45' W. Depth of station, 36·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·35	18·98	34·29	26·00
9·2	12·35	18·95	34·23	25·96
18·3	12·35	18·96	34·25	25·97
36·6	12·4	18·96	34·25	25·97

6/11/07 (3-50 p.m.) 52° 24' N.; 4° 43' W. Depth of station, 36·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	$\sigma_t$
0	12·1	18·84	34·04	25·85
9·2	12·15	18·82	34·00	25·81
18·3	12·3	18·84	34·04	25·81
34·8	12·2	18·85	34·05	25·84



A careful consideration of the above tables will show that:—

(1) In the majority of cases the water at any given spot has practically the same salinity from top to bottom. There are, however, some well-marked exceptions to this, the stations affected being in the shallower water north of the 54 parallel of latitude. In these exceptional cases there is a more or less rapid increase in salinity with depth. The probable explanation of this will be discussed presently.

(2) There is a small but unmistakeable seasonal variation in the salinities.

To bring out this second point more clearly the salinities at the chief stations for the various months have been collected in the following table. In most cases the salinities have been given to the first place of decimals, and in the case of those stations in which the water at the surface differed markedly in salinity from that at the bottom both top and bottom salinities have been given.

For the present purpose those positions which are bracketed may be considered as one station.

In so far as one is justified in drawing conclusions from only a year and a-half's work, it would appear that at the first four stations the salinity is at a minimum somewhere about February. The maximum salinity is not so well marked but seems to occur between July and November.

In the case of stations 5 and 6 exactly the reverse holds, the maximum salinity occurring in February and the minimum in November. Station 7 which, like 5 and 6, is on the line Holyhead—Calf of Man, resembles stations 1-4 from the fact that the minimum salinity occurs about February.

This difference in the time of minimum salinity is

Position	July 1906	Sept. 1906	Nov. 1906	Feb. 1907	May 1907	July 1907	Nov. 1907
54° N. ; 3° 30' W. } 1	—	—	—	—	—	{ 31·87 32·75	{ 33·1 33·3
54° 1' N. ; 3° 31' W. }	—	—	—	32·3	{ 32·56 32·86	—	—
54° 3' N. ; 3° 22' W. }	32·8	33·0	33·4	—	—	—	—
54° N. ; 3° 47' W. } 2	—	—	—	—	—	{ 33·73 33·80	{ 33·64 33·66
54° 2' N. ; 3° 47' W. }	—	—	—	32·92	{ 33·42 33·55	—	—
54° 7' N. ; 3° 36' W. }	{ 32·8 33·2	{ 33·2 33·5	33·6	—	—	—	—
54° N. ; 4° 4' W. }	—	—	—	—	—	34·05	33·9
54° 2' N. ; 4° 4' W. }	—	—	—	33·2	33·7	—	—
54° 10' N. ; 3° 50' W. }	{ 32·8 33·4	{ 33·3 33·4	33·0	—	—	—	—
54° N. ; 4° 20' W. }	—	—	—	—	—	34·1	33·9
54° 3' N. ; 4° 20' W. }	—	—	—	33·5	34·3	—	—
54° 14' N. ; 4° 2' W. }	{ 33·3 33·5	33·46	33·0	—	—	—	—
53° 53' N. ; 4° 46' W. }	—	—	—	34·4	{ 34·3 34·4	34·1	34·0
53° 56' N. ; 4° 47' W. }	34·2	34·0	33·9	—	—	—	—
53° 43' N. ; 4° 44' W. }	—	—	—	34·3	34·3	34·1	33·95
53° 47' N. ; 4° 45' W. }	34·15	34·1	34·0	—	—	—	—
53° 33' N. ; 4° 41' W. }	—	—	—	33·8	33·95	34·0	33·7
53° 38' N. ; 4° 43' W. }	34·1	34·1	34·0	—	—	—	—
53° 5' N. ; 4° 44' W.	—	—	—	—	34·2	34·1	34·6
52° 34' N. ; 4° 45' W.	—	—	—	—	34·04	34·05	34·3
52° 24' N. ; 4° 43' W.	—	—	—	—	33·98	33·9	34·0

probably due to the way in which the mixing of the fresher and salter water is brought about by the tides, which cause the salter water at stations 5 and 6 to be gradually diluted by the less salt water from further north. This will obviously result in the minimum salinity at stations 5 and 6 roughly corresponding with maximum salinity at the more northerly stations. The different behaviour at station 7 is no doubt due to the fact that at that point the tide running north is much stronger than that running south, so that there is a continuous slight stream from the south.

These last considerations make it clear that in considering the seasonal variation of salinity, the effect of the tides must be borne in mind.

As already mentioned, the portion of the Irish Sea with which the present investigations deal is noted for its strong tides, so it seemed likely that the salinity at any given spot would depend to a slight extent on the state of the tide: as this changed, so the water originally present would be replaced by other water which might well differ in salinity. It was important to see whether any differences so caused were appreciable and likely to mask any seasonal change in the salinity. Samples were accordingly collected from one of the stations every two hours throughout a tidal cycle. The station chosen was that at  $54^{\circ} 2' \text{ N.}; 3^{\circ} 47' \text{ W.}$ , as being one at which any such effect would probably be well marked owing to the proximity of the large body of water of low salinity in Morecambe Bay.

The results obtained are given in the following table:

July 2, 1907. 54° 2' N.; 3° 47' W. (Sea smooth and weather fine all day.)

Depth	T°	Cl ‰	S ‰	$\sigma_t$	
0	11·6	18·57	33·55	25·56	} 6.30 a.m. ; 2 h. 20 min. after High Water.
9·2	11·4	18·56	33·53	25·56	
44·7 (bottom)	11·4	18·62	33·64	25·67	
0	12·0	18·60	33·60	25·53	} 8.30 a.m. ; 4 h. 20 min. after High Water.
9·2	11·5	18·57	33·55	25·58	
40·3 (bottom)	11·4	18·63	33·66	25·68	
0	12·1	18·57	33·55	25·47	} 10.30 a.m. ; Low Water.
9·2	11·45	18·63	33·66	25·66	
40·3 (bottom)	11·3	18·64	33·68	25·71	
0	12·05	18·46	33·35	25·34	} 12.30 p.m. ; 4 hrs. before High Water.
9·2	11·4	18·62	33·64	25·66	
40·3 (bottom)	11·2	18·65	33·69	25·74	
0	12·4	18·58	33·57	25·42	} 2.30 p.m. ; 2 hrs. before High Water.
9·2	11·55	18·58	33·57	25·50	
40·3 (bottom)	11·2	18·67	33·73	25·77	
0	12·1	18·59	33·58	25·50	} 4.30 p.m. ; High Water.
9·2	11·6	18·61	33·62	25·62	
40·3 (bottom)	11·2	18·66	33·71	25·76	

It is clear from the above that at any rate at some stations a variation in salinity due to the tide alone does occur. The variation, as was to be expected, is greatest for the surface water and least for the ground water:—The maximum variation at the surface in the above experiment was 0·23; at 9·2 metres it was 0·13 and at the bottom only 0·09.

Now the maximum change of salinity for the same station between February and November, 1907, was 0·81 for the surface and 0·88 for the bottom water. There can be no doubt, therefore, that a small seasonal change in



the salinities occurs, as had already been concluded from the results summarised in the last table but one.

The change due to the tide will certainly, in most cases, be much smaller than that found above. On the line Holyhead—Calf of Man it will probably be undetectable, and on the line Piel Gas Buoy—Calf of Man will probably be greater the nearer the point considered is to the English coast.

Nothing has as yet been said of the temperatures of the water samples. These, of course, are higher in the summer than in the winter. The surface water is in many cases somewhat warmer than the underlying, but in other cases it is the same. From 9·2 metres downwards the temperature is fairly constant. In the case of one or two of the deeper stations there is sometimes a notable diminution in the temperature with depth, and in the case of some of the shallower stations the temperatures are rather irregular. In the shallower water this is probably connected with tidal currents.

A few words may finally be said about the position of certain isohaline lines in this area. That for salinity 34 probably starts at Burrow Head, Wigtownshire, runs across to a point a little west of the Point of Ayre, starts again at the Calf of Man and runs across to Holyhead. It then crosses Carnarvon Bay, making a slight curve inwards, and then goes in almost a straight line across Cardigan Bay, ending near Cardigan. This may be regarded as a sort of mean position about which it will vary with the season, so that, for instance, the portion between the Calf of Man and Holyhead will sometimes (about May) make a considerable bend to the east. The salinity of all the water to the east of this line will be below 34. The 33 isohaline is clearly much more affected by seasonal

changes, but the details available are not sufficient to justify speculations as to its course.

The seasonal variations of salinity found in the area with which this paper deals are probably entirely due to variations in rainfall and in the amount of fresh water flowing into the sea from the land.

CHEMICAL DEPARTMENT,  
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AN EXAMINATION OF THE OBSERVATIONS  
MADE ON THE BLACKPOOL CLOSED GROUND  
DURING THE PERIOD 1892 TO 1906.

(Plate IV.)

By H. J. BUCHANAN WOLLASTON.

The statistics for the Closed Ground off Blackpool deal with 327 hauls made with shrimp-trawl, shank-net, and fish-trawl. Table I. is an analysis of the hauls. In three years, 1899, 1901, and 1902, no hauls were taken with the shank-net. As our aim is to form some idea of the variation in the number of young fish from month to month, or year to year, it is obviously of little value to consider the catches of the fish trawls, which have large meshes and are constructed to avoid as much as possible the capture of young fish. We have to resort then to hauls taken with the shrimp-trawl and shank-net for results.

The numbers of hauls were found to be quite insufficient to give useful results if taken monthly. They have, therefore, been taken in seasons of three months each, viz., January to March, April to June, July to September, and October to December, as will be seen on reference to Table I.

The relation between the shrimp-net and shank-net in catching power is shown in Table II. The results were obtained by averaging groups of hauls taken with the two kinds of net as far as possible on the same day and under similar conditions. The averages of the values thus obtained were then reduced to hourly catch, thus giving a fairly reliable picture of the relation between the nets in taking-power. The shank-net thus appears to be far superior to the shrimp-trawl in avoiding the capture of

TABLE I.

Showing Number of Hauls taken on Blackpool Closed  
Ground with Shrimp Trawl, Shank Net, and Fish  
Trawl during the years 1892 to 1906 inclusive.

Net used	Shrimp Trawl				Shank Net				Fish Trawl				Totals of all nets for the periods				Yr'ly T'tls, all nets
Year.	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.	All peri- ods.
1892	0	2	4	2	0	3	0	4	0	0	0	0	0	5	4	6	15
1893	0	0	3	6	5	5	2	3	0	0	1	0	5	5	6	9	25
1894	3	3	2	2	5	4	6	1	0	0	11	0	8	7	19	3	37
1895	4	8	3	3	0	2	1	0	0	4	3	3	4	14	7	6	31
1896	1	1	0	0	4	2	4	6	1	1	4	2	6	4	8	8	26
Quint. totals	8	14	12	13	14	16	13	14	1	5	19	5	23	35	44	32	134
1897	1	1	0	3	6	4	2	6	0	0	5	3	7	5	7	12	31
1898	1	0	3	1	2	0	4	0	0	1	0	0	3	1	7	1	12
1899	0	0	3	0	0	0	0	0	0	1	1	0	0	1	4	0	5
1900	3	0	0	0	4	6	4	0	0	0	0	0	7	6	4	0	17
1901	3	3	1	1	0	0	0	0	0	0	3	0	2	3	4	1	10
Quint. totals	7	4	7	5	12	10	10	6	0	2	9	3	19	16	26	14	75
1902	10	6	2	3	0	0	0	0	0	2	1	1	10	6	3	4	23
1903	5	2	2	1	18	8	2	2	0	0	2	2	15	10	5	7	37
1904	0	6	1	0	5	3	0	0	0	3	3	0	5	11	5	0	21
1905	2	2	2	3	3	3	0	0	0	2	8	3	5	7	11	6	29
1906	0	0	1	0	0	0	1	0	0	2	4	0	0	2	6	0	8
Quint. totals	17	13	9	7	18	14	3	4	0	9	18	6	35	36	30	17	118



TABLE II.

Net used	Average number of Shrimps per hour	Average number of Undersized Fishes per hour	Average number of Young Fishes taken with each quart of Shrimps
Shrimp Trawl...	5 $\frac{1}{3}$ Quarts	6,175 $\frac{7}{8}$	1,155
Shank Net .....	6 $\frac{2}{7}$ ,,	1,642 $\frac{2}{3}$	239 $\frac{5}{9}$

young fish, and this with no loss or even a small gain in capture of shrimps. The shank-net hauls were made partly with the ordinary form, and partly with the patent Bar-net. Table III. shows the relation between the

TABLE III.

Kind of net used	Average number of Undersized Fishes per hour	Average number of Shrimps per hour	Average number of Undersized Fishes taken with each quart of Shrimps
Ordinary Shank	553	2·1	263·3
Bar Shank .....	508·5	2·2	231

catching-powers of these two nets, the values being obtained in a similar way to those for shrimp-trawl and shank-net. It will be seen that the bar-net is slightly the superior both in avoidance of young fish and in capture of shrimps. Tables IV. and V. give the average catches per hour with one shank-net and one shrimp-trawl respectively, of plaice, dabs and shrimps on the Blackpool Closed Ground for the four seasons. The figures were

TABLE IV.

Showing Average Catch per hour of Shrimps and  
Undersized Fishes with Shank Net.

Season	January to March			April to June			July to September			October to December		
Year	Shrimps Pts.	Plaice No.	Dabs No.	Shrimps Pts.	Plaice No.	Dabs No.	Shrimps Pts.	Plaice No.	Dabs No.	Shrimps Pts.	Plaice No.	Dabs No.
1892	0	0	0	3	112	78	—	—	—	22 $\frac{1}{4}$	956	2970
1893	15 $\frac{1}{2}$	236	770	6 $\frac{3}{4}$	31	86	$\frac{1}{2}$	223	207	17 $\frac{1}{4}$	2293	864
1894	16 $\frac{3}{4}$	631	1227	2 $\frac{3}{4}$	80	155	5 $\frac{1}{4}$	96	119	—	—	—
1895	—	—	—	4 $\frac{3}{4}$	37	54	18	72	33	—	—	—
1896	14 $\frac{1}{2}$	392	1625	1 $\frac{1}{4}$	71	23	$\frac{1}{2}$	114	449	11 $\frac{1}{2}$	39	350
Quint. totals.	15 $\frac{1}{2}$	420	1207	3 $\frac{3}{4}$	66	79	6	151	202	17	1096	1395
1897	1 $\frac{1}{4}$	70	130	3 $\frac{3}{4}$	137	82	6	26	32	2	12	72
1898	12	51	752	—	—	—	4 $\frac{1}{2}$	11	8	—	—	—
1899	—	—	—	—	—	—	—	—	—	—	—	—
1900	7	9	1476	6	19	173	$\frac{1}{2}$	6	10	—	—	—
1901	—	—	—	—	—	—	—	—	—	—	—	—
Quint. totals.	6 $\frac{3}{4}$	43	786	5	78	127	3 $\frac{2}{3}$	14	17	2	12	72
1902	—	—	—	—	—	—	—	—	—	—	—	—
1903	10 $\frac{1}{2}$	18	729	5	20	529	6 $\frac{1}{2}$	3	33	21 $\frac{1}{2}$	2	889
1904	8	4	3634	1	9	85	—	—	—	—	—	—
1905	1 $\frac{1}{4}$	64	707	$\frac{2}{3}$	70	32	—	—	—	—	—	—
1906	—	—	—	—	—	—	—	—	—	—	—	—
Quint. totals	6 $\frac{1}{2}$	29	1890	2 $\frac{1}{4}$	33	182	6 $\frac{1}{2}$	3	33	21 $\frac{1}{2}$	2	889

TABLE V.

Showing Average Catch per hour of Shrimps and  
Undersized Fishes with Shrimp Trawl.

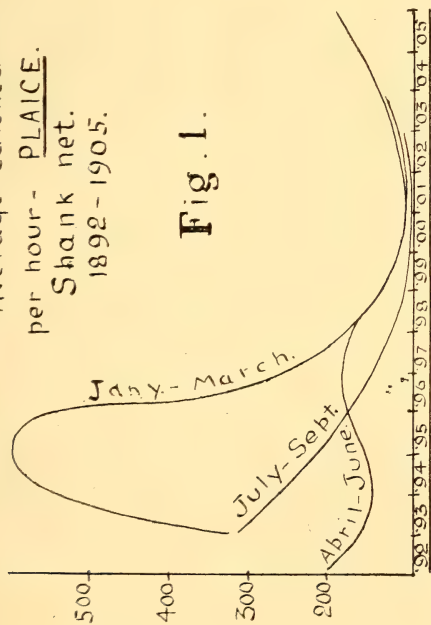
Season	January to March			April to June			July to September			October to December		
Year	Shrimps Pts.	Plaice No.	Dabs No.	Shrimps Pts.	Plaice No.	Dabs No.	Shrimps Pts.	Plaice No.	Dabs No.	Shrimps Pts.	Plaice No.	Dabs No.
1892	—	—	—	2	310	210	7½	490	126	11	1	2419
1893	—	—	—	—	—	—	6	2916	3966	26	2182	7862
1894	17½	3036	2864	¾	712	455	—	—	—	13½	617	10785
1895	6¼	751	2129	½	273	313	½	1106	254	12¼	2165	8851
1896	36	2756	15200	5	543	121	—	—	—	—	—	—
Quint. totals	20	2183	6731	2	459	275	5	1504	1449	15¾	1241	7479
1897	2½	326	4572	0	209	102	—	—	—	1¾	57	1637
1898	0	606	399	—	—	—	15	389	1872	14	508	1627
1899	—	—	—	—	—	—	1¾	74	366	—	—	—
1900	16½	100	3509	—	—	—	—	—	—	—	—	—
1901	15	286	7399	1	214	517	0	135	340	1	130	10280
Quint. totals	8½	329	4722	½	212	309	5½	423	859	5½	232	4511
1902	5¾	332	5305	2¾	244	2159	3	99	1301	1½	174	1865
1903	18	209	14121	2	34	745	6	42	929	32	20	18050
1904	—	—	—	9¼	40	857	12	16	608	—	—	—
1905	6¾	125	6152	0	59	391	4	74	499	6¾	7	1253
1906	—	—	—	—	—	—	0	196	2000	—	—	—
Quint. totals	10¼	222	8526	3½	94	1038	5	85	1067	13½	67	7056

obtained by averaging all the hauls taken in the season in question and reducing to average catch per hour. As the figures are too irregular for it to be possible to form any idea of variation directly from the tables, curves were drawn through points representing the values to be examined. Fig. 4 is a curve drawn through points corresponding to the average catch per hour with shank-net of dabs in the four seasons. To eliminate the small yearly difference in this variation, the whole period of fifteen years was considered. Fig. 3 is the curve of the same values for the shrimp-trawl. These show that the maximum catches of dabs are made in the winter, from November to February, and the minimum catches in the summer, from May to July. The very low position of the curves in June and July should not be taken as representing the actual values, but as indicating the probability that if an average were obtainable for the catches taken at this time, it would be lower than the averages for catches either before or after it. Figs. 1 and 2 are the curves for yearly variation in number of plaice caught per hour on the ground with shrimp-trawl and shank-net respectively, each curve representing the same season throughout the fifteen years considered. The curves have not been drawn through the points representing the actual values, but have been smoothed in the same way as were the monthly averages for the Mersey Banks (see page 179), so that irregular variations are disregarded and the general tendency of the figures shown. Both sets of curves show a marked decrease in the number of plaice taken per hour on the Closed Ground since 1892. This decrease is least visible in the curve for April to June. Other curves have been drawn, but are not included, as they show little sign of any regular variation. Thus, the curves for hourly catch of shrimps are so irregular that no deductions could

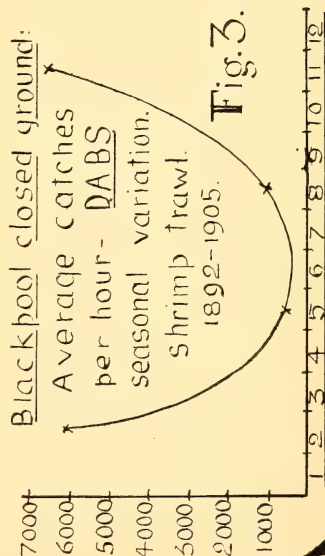


possibly be drawn. The curves of yearly variation in hourly catch of dabs show that the fluctuations in numbers caught are mainly confined to the winter seasons, October to March, being then about four times as great as in the summer.

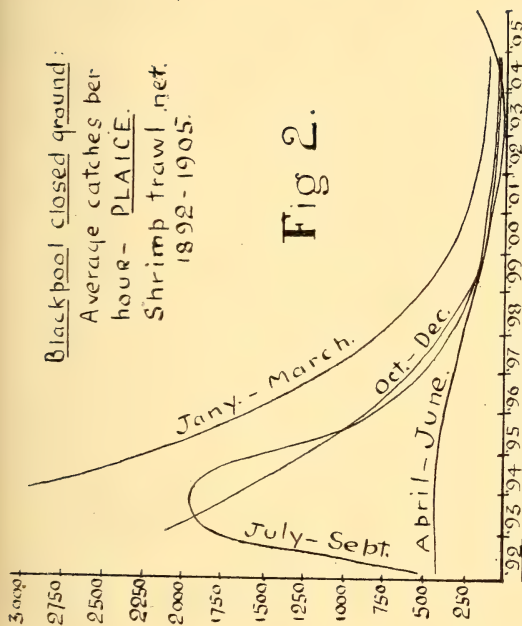
Blackpool closed ground:  
Average catches  
per hour - PLAICE.  
Shank net.  
1892-1905.



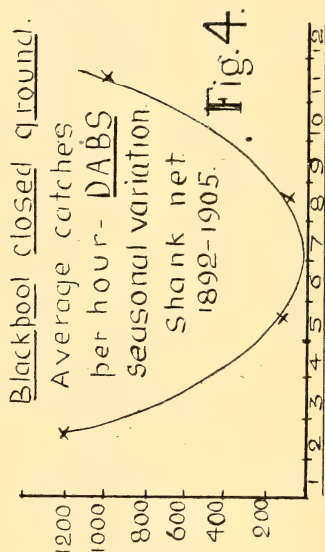
Blackpool closed ground:  
Average catches  
per hour - DABS  
seasonal variation.  
Shrimp trawl.  
1892-1905.

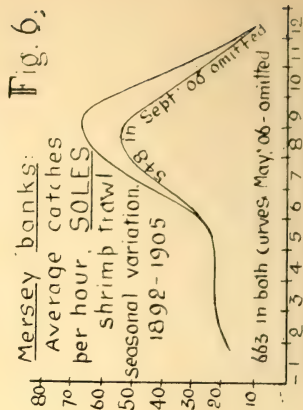
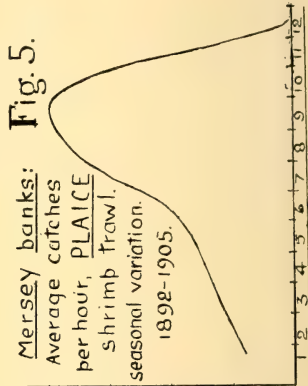
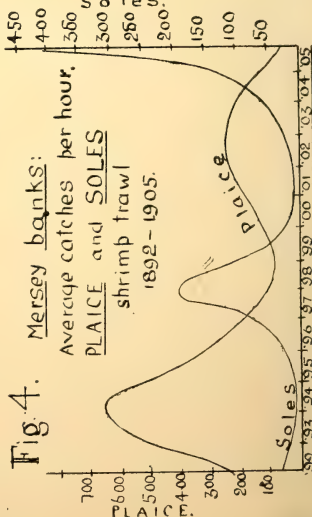
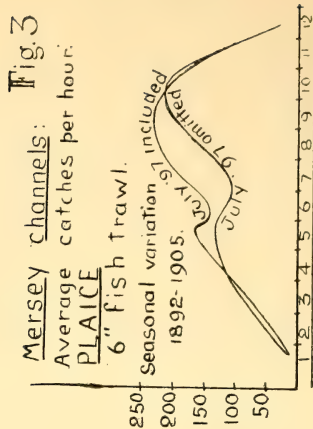
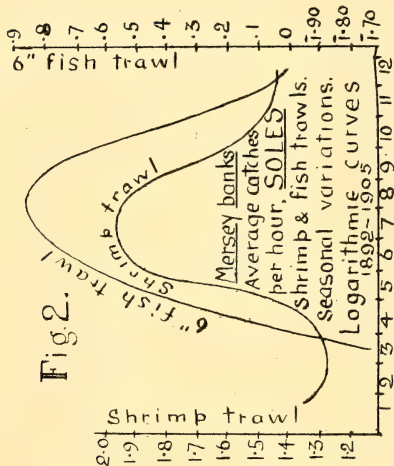
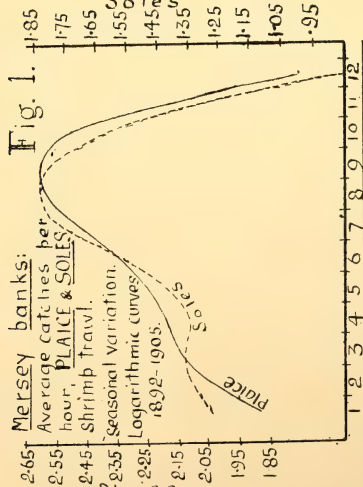


Blackpool closed ground:  
Average catches per  
hour - PLAICE.  
Shrimp trawl net.  
1892-1905.



Blackpool closed ground.  
Average catches  
per hour - DABS  
seasonal variation  
Shank net  
1892-1905.





AN EXAMINATION OF THE EXPERIMENTAL  
HAULS MADE IN THE MERSEY ESTUARY  
DURING THE PERIOD 1892 TO 1906  
INCLUSIVE.

(Plate V.)

By H. J. BUCHANAN WOLLASTON.

The present paper deals with the records of the experimental hauls made on the Mersey Banks and in the adjoining Channels, by the L. and W.S.F. steamer "John Fell," and the New Brighton police cutter. The material consists of several hundred sheets, dealing with nearly 800 hauls—there being 260 hauls made with shrimp-trawl nets, 70 with fish-trawls of various forms, and 13 with shank-nets, all on the banks; also 281 with fish-trawls, 163 with shrimp-trawls, and 3 with shank-nets, all taken in the channels between the banks. It was evident on examination of the records that the number of hauls made with fish-trawls on the banks, and with shank-nets both on the banks and in the channels were quite insufficient to afford reliable conclusions. The shrimp-trawl-net hauls, both in the channels and on the banks, and the six inch fish-trawl-net hauls in the channels, are, however, sufficiently numerous to warrant statistical treatment, and the results have some interest, especially with regard to the variations from month to month in the numbers of plaice and soles on the banks. The method adopted was as follows: Every haul was separately reduced to an hourly catch, that is, to take a simple case, if the haul was of two hours' duration the result was divided by 2. From all the hauls in each month so reduced, an average haul was calculated, giving the numbers of plaice and soles caught per hour's fishing. The observations were, however, made rather irregularly, and so in order to get a more reliable average catch per hour for each month, the whole period of fifteen years

(1892-1906) was considered, that is, for instance, all the average hourly hauls for January were added together, and a new average, giving the number of fish caught per hour's fishing for the month of January (1892-1906), was thus obtained. Similarly, to find the yearly variation, which was only possible in the case of the summer months, owing to lack of data for the winter, an average hourly catch for the six-monthly period, May to October, was obtained in each year, and the variation of this average from year to year was studied. Curves were drawn through points corresponding to these averages, and since it was found that these points were too irregularly distributed to give reliable results, they were modified in the following manner:—The values representing the average catches were arranged in chronological order, and the first and last were taken as correct. For each of the other monthly averages a new value was substituted, obtained as follows:—The average catches for the month in question and that immediately preceding and succeeding it were added together and the sum divided by three. This is the well-known statistical device of "taking three-monthly averages monthly." In some cases the figures thus obtained had to be again treated in the same way before it was found possible to draw a really smooth curve through the points, showing distinct maxima and minima. The following figures, those for average catches of plaice with the shrimp-trawl net, will serve to show the method.

Original Figures.		First Smoothing.
Jan. ....	72 ... (taken as correct) ...	72
Feb. ....	93 ... $\frac{72 + 93 + 182}{3}$ ...	116
Mar. ....	182 ... $\frac{93 + 182 + 94}{3}$ ...	123
April ....	94 ... $\frac{182 + 94 + 155}{3}$ ...	144
May ....	155 ...      ...      ...      &c.	
&c.		



This method may appear somewhat artificial, but is not so in reality to any great extent, as it merely means that the values of the numbers for the months immediately before and after each given month are allowed an influence in determining the new values for that month.

Now if we proceed to construct curves showing the variation in the average hourly catches of plaice and soles made per month on the banks, we notice a distinct similarity in the shapes of these curves, i.e., where there is an increase in the number of plaice, there is also an increase in the number of soles, and vice versâ. We do not, however, know whether the rate of increase is the same in the two cases, that is, for instance, whether a 10 per cent. increase in plaice would correspond with a 10 per cent. increase in soles. Now, in order to find whether this rate of increase is the same or different, we may take, instead of the actual numbers of plaice and soles caught, the logarithms of those numbers, and the curves constructed from the latter values show the relation between the rates of increase and decrease, that is to say, if the two curves have the same shape and height the rate of increase is the same in the two cases. This has been done (figs. 1, 2) for the monthly variation of plaice and soles on the Mersey banks, and also for the monthly variation of average hourly catch of soles with shrimp-trawl and six inch mesh fish-trawl.

We are now in a position to attempt to draw conclusions from the results obtained by the above methods. The data are not sufficient to warrant any conclusion regarding yearly variation except in the case of numbers of plaice and soles caught by the shrimp-trawl net on the banks in the summer months. The curves plotted from these values seem to indicate a complementary relation-

ship, plaice increasing as soles decrease, and vice versâ (see fig. 4).

In the monthly variation there is, on the other hand, direct correspondence between the hourly catches of plaice and soles on the banks with the shrimp-trawl (see figs. 5, 6), plaice increasing as soles increase, and at approximately the same rate (see fig. 1), though the period of greatest abundance is slightly earlier in the case of soles than in that of plaice, the maximum for soles being in August, while that for plaice is in September. Regarding plaice taken in the channels no very reliable conclusion can be drawn, the data being too scanty, but the greatest catches seem to have been made at the same time as on the banks (see fig. 3). In the case of soles taken in the channels, the curves of average catches with shrimp-trawl and six inch fish-trawl show distinct relation to each other, both as to the position of the maximum catches and in rate of increase (see fig. 2), that is to say, if large soles increase, small soles increase in approximately the same proportion. The maximum is somewhat earlier for soles in the channels than on the banks.

In dealing in the future with separate yearly returns, the curves given here for monthly variation might be regarded as the standard forms, and the curve of monthly variation for any single year, if it differs widely from these standards, might be looked upon as rather exceptional. Of course these curves may differ considerably in different localities.

The tables of monthly averages, and the curves of monthly and yearly variation mentioned above are appended:—

AVERAGE CATCH PER HOUR OF PLAICE AND SOLES ON THE  
MERSEY BANKS WITH SHRIMP-TRAWL.

	January	February	March	April	May	June	July	August	September	October	November	December	
1892	.....	.....	.....	.....	.....	.....	90 44	153 21	.....	537 3	86 0	.....	Plaice Soles
1893	45 0	129 5	.....	.....	115 2	494 12	.....	707 34	2405 31	373 3	195 1	81 0	Plaice Soles
1894	217 7	134 5	295 60	178 15	661 31	402 38	170 20	556 16	571 10	225 8	.....	.....	Plaice Soles
1895	6 0	.....	25 0	57 1	55 18	59 6	586 24	456 29	2315 5	813 0	189 0	62 0	Plaice Soles
1896	.....	.....	594 4	279 0	317 3	568 10	914 23	206 1	.....	120 42	.....	.....	Plaice Soles
1897	.....	94 34	.....	102 6	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1898	.....	.....	.....	.....	.....	.....	111 190	130 339	92 119	85 155	.....	.....	Plaice Soles
1899	.....	.....	.....	.....	.....	40 22	30 43	167 127	95 105	10 38	.....	.....	Plaice Soles
1900	.....	.....	.....	9 20	.....	51 46	35 13	133 50	72 4	.....	.....	.....	Plaice Soles
1901	.....	.....	8 8	1 3	1 23	100 26	45 23	661 63	388 12	423 2	80 1	1 0	Plaice Soles
1902	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1903	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1904	.....	.....	.....	.....	18 7	.....	.....	.....	459	.....	4 22	44 0	Plaice Soles
1905	2807 0	20 3	7 0	28 7	21 38	116 5	58 170	78 20	122 3	24 168	40 25	34 9	Plaice Soles
1906	21 85	88 45	163 115	103 111	53 663	55 37	.....	.....	22 548	.....	.....	5 35	Plaice Soles

AVERAGE CATCH PER HOUR OF PLAICE AND SOLES IN THE  
MERSEY CHANNELS WITH SHRIMP-TRAWL.

	January	February	March	April	May	June	July	August	September	October	November	December	
1892	.....	.....	.....	95 4	13 10	.....	.....	301 35	.....	881 1	383 1	107 0	Plaice Soles
1893	.....	115 2	147 6	201 5	248 10	288 5	.....	46 14	594 27	263 4	304 0	440 0	Plaice Soles
1894	420 0	296 7	.....	.....	246 19	433 31	315 47	122 6	.....	.....	.....	201 0	Plaice Soles
1895	.....	.....	20 0	31 0	46 6	337 44	.....	.....	166 11	35 0	822 0	.....	Plaice Soles
1896	1197 0	365 0	.....	979 13	.....	.....	.....	.....	120 57	.....	.....	.....	Plaice Soles
1897	129 34	126 116	.....	.....	.....	.....	.....	1278 197	343 31	111 48	.....	.....	Plaice Soles
1898	1652 90	.....	.....	.....	.....	.....	632 275	49 125	164 133	810 148	75 190	.....	Plaice Soles
1899	.....	.....	.....	.....	.....	37 89	.....	11 4	73 31	51 24	.....	.....	Plaice Soles
1900	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1901	.....	6 0	23 6	.....	1 11	63 5	.....	.....	.....	.....	110 0	.....	Plaice Soles
1902	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1903	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1904	.....	.....	.....	.....	17 150	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1905	39 2	.....	50 37	277 1	.....	.....	.....	.....	.....	.....	.....	3 112	Plaice Soles
1906	.....	23 71	.....	.....	58 119	6 41	.....	.....	.....	256 3	599 3	.....	Plaice Soles



**AVERAGE CATCH PER HOUR OF PLAICE AND SOLES IN THE MERSEY CHANNELS  
WITH 6IN. FISH TRAWL.**

	January	February	March	April	May	June	July	August	September	October	November	December	
1892	.....	.....	.....	.....	8 0	35 2	198 1	33 1	83 2	.....	.....	.....	Plaice Soles
1893	.....	30 0	13 0	.....	.....	.....	150 2	463 0	73 2	161 2	.....	5 4	Plaice Soles
1894	.....	.....	.....	.....	.....	.....	.....	.....	1027 0	.....	.....	.....	Plaice Soles
1895	.....	.....	.....	.....	.....	.....	.....	.....	322 0	612 0	.....	.....	Plaice Soles
1896	.....	.....	.....	.....	.....	.....	34 2	.....	.....	967 0	.....	.....	Plaice Soles
1897	.....	.....	.....	.....	.....	.....	3211 0	.....	.....	.....	.....	.....	Plaice Soles
1898	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1899	.....	.....	.....	.....	.....	29 3	.....	.....	.....	.....	.....	.....	Plaice Soles
1900	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Plaice Soles
1901	.....	.....	.....	.....	.....	.....	1 : 7 8 : 11	.....	.....	.....	32 : 283 5 : 0	.....	Plaice Soles
1902	.....	22 0	.....	.....	639 0	.....	50½ 7	437 5	.....	.....	.....	.....	Plaice Soles
1903	.....	.....	.....	294 0	.....	131 : 30 13 : 9	41 8	143 : 165 4 : 9	.....	.....	.....	7 0	Plaice Soles
1904	.....	2 0	26 0	.....	.....	.....	54 : 26 16 : 3	6 44	42 : 0 9 : 13	55 7	.....	.....	Plaice Soles
1905	.....	.....	100 0	2 1	48 5	11 10	29 23	.....	.....	566 : 298 1 : 0	66 : 39 0 : 0	.....	Plaice Soles
1906	0 0	.....	.....	.....	.....	30 0	10 16	10 4	22 : 74 5 : 3	80 : 182 0 : 1	.....	.....	Plaice Soles

NOTE.—Where there are two numbers in one line in any square the second is the average of hauls made with a fish-trawl having pockets and tails of 6in. mesh, the other that for the ordinary 6in. mesh trawl.



# AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.

BY W. A. HERDMAN, F.R.S., AND ANDREW SCOTT, A.L.S.

## INTRODUCTORY.

The objects of this detailed investigation into the Plankton of a limited marine area are twofold:—

(1) To study the distribution of the Plankton as a whole and of its various constituents during the year, and

(2) To attempt to arrive at some estimate of the representative value of such samples as are collected in our plankton nets.

Of the fundamental importance of plankton work in regard to fishery questions of a wide nature there can be no doubt, and of the absolute necessity of the determination of the value of samples and of arriving at some estimation of their representative nature there can be still less difference of opinion.

In former reports\* we have shown that our results around the Isle of Man and in other parts of the Irish Sea show great diversity in the plankton, both quantitatively and qualitatively when considered according to locality or according to date but in all these former reports we have felt that fuller information might enable us to reduce the apparent chaos to order, and might reveal some method or definite sequence in a distribution which seemed indefinite or irregular. Consequently we have endeavoured during the last year to make our observations as frequent, full

\* Twentieth Annual Report of the Liverpool Marine Biology Committee, Dec., 1906; Presidential Address to the Linnean Society of London, May, 1907; and Twenty-first Annual Report of the L.M.B.C., Dec., 1907.

and detailed as possible, and the result is that we have now at our disposal a much larger number of samples than has ever been collected before in such a limited period from the Irish Sea—possibly a greater number of samples than has been obtained in one year from any other part of the British coasts. The total number is 885 obtained from our northern portion of the Irish Sea bounded by lines drawn between Holyhead, Liverpool, Barrow and Port Erin, in the year 1907; and of these the majority, 650, are from a very limited area in the immediate neighbourhood of Port Erin.

At the South end of the Isle of Man, where these gatherings were taken, there are very important fishing grounds which are frequented by trawlers from Lancashire and from Ireland, as well as by the Manx fishermen. This, as well as the circumstance that we have there, within a few miles, a sheltered sandy bay, an exposed rocky coast, a narrow strait and an area of open sea with depths reaching to 70-80 fathoms, has led us to consider Port Erin a very suitable locality for a more exhaustive or intensive study of the Marine Plankton than has yet been attempted on our coast.

#### PREVIOUS LOCAL WORK.

The Liverpool Marine Biology Committee started a scheme for taking weekly plankton gatherings in this district of the Irish Sea as long ago as 1888, and although as the result of weather, changes in the staff and other varying conditions, many gaps have been left from time to time in the series, that aim has been constantly before us, and the practice has been kept up intermittently. A good deal of material was collected from the neighbourhood of Puffin Island, and from Port Erin in these early years, and was examined and reported upon by the late

Mr. Isaac C. Thompson. In 1897 a more definite scheme was organised for the collection of plankton weekly from six different localities off the coasts of Lancashire, Cheshire and the Isle of Man; and the material so gathered was examined, and reported upon, as part of the Sea Fisheries work of the district. The Annual Reports of the Liverpool Marine Biology Committee and the Lancashire Sea Fisheries Laboratory Reports contain, from time to time, articles on the plankton of the Irish Sea or scattered notices of occurrences. Thus Mr. E. T. Browne, working at Port Erin from April to June, 1893, noted that *Ceratium tripos*, *C. fusus* and *Peridinium divergens* were nearly always present in his gatherings; that there was "a great decrease of Copepoda when the sea is full of Diatoms"; and that *Oikopleura* is abundant with ova at the end of April, and that the young individuals are found at the end of May. Mr. H. C. Chadwick, in 1894, recorded the abundance of larval and post-larval worms in May, in an article on "Plankton Observations," in the Report for 1897 (p. 17). He noted a great abundance of Diatoms in spring, an increase of pelagic Coelenterata and Copepoda in early summer, the appearance of fish-eggs and embryos and larval fish at Easter, a great increase in Medusae and Ctenophora in later summer, and the abundance of Dinoflagellates in late summer and autumn.

A summary account of the Port Erin plankton throughout the year was given in 1899 (13th Report, p. 29), and in this the maximum of Diatoms at the end of March is noted, also a maximum of larval forms in the last weeks in June, of Medusae in July, and of Zoeas and other Decapod larvae towards the end of August. *Oikopleura* attained its maximum that year at the end of September. The presence of the three species of

Ceratium—*C. tripos*, *C. fusus* and *C. furca*—throughout the year is also noted.

In the Sea Fisheries Laboratory Report for 1892 the great profusion of Diatoms in the spring, and their replacement later on by Copepoda, was drawn attention to. In the Reports for 1904, 1905 and 1906 there were special articles on the Plankton of the Irish Sea, in which the spring maximum of the Diatoms and other features of the distribution throughout the year were noted. In the 1905 Report, 365 gatherings had been examined, and in the following year (1906) 400 gatherings. These numbers, the largest up to that date, have, however, been more than doubled on the present occasion (1907).

In these previous accounts we have used the terms "numerous," "abundant," &c., or the symbols "r" (rare), "c" (common), "fr" (frequent), &c., as is usually done by other investigating authorities; but this year we have adopted the plan of counting the organisms in a number of samples from each gathering, and of estimating from these the approximate total numbers of each kind of organism present. The exact method employed has been as follows:—

#### METHOD OF ESTIMATION.

After carefully removing pieces of sea-weed and other foreign matters, the sample is thoroughly shaken up and then allowed to stand and settle for a week. In the case of a very small catch, the sample is first transferred to a narrow tube. After standing for a week, a mark is made on the bottle, indicating the exact height occupied by the organisms. The whole sample is then washed through a silk sieve of 36 meshes to the inch, into one of 200 meshes to the inch. By this process the Diatoms, Dinoflagellates and allied minuter organisms, along with the Copepod Nauplii and young Copepoda, are



separated from the larger organisms such as *Sagitta*, larval Decapods, and adult Copepoda, except perhaps *Oithona*. The two portions thus obtained are carefully transferred to graduated tubes, so that they can be each made up to a known bulk with fresh water. The larger organisms are examined first. If the bulk of the catch which is left on the coarse silk sieve is not large, then a direct enumeration of the organisms can be made at once by turning the contents of the tube on to a glass plate with a dark background and examining the animals in a good light with a strong hand magnifying glass, or low power of the microscope if necessary. The various species are recorded as the sample is gone over, and the totals are added up at the end of the examination. If the sample to be examined, however, be too large for a direct and complete enumeration, then it is first gone over carefully and the rarer or larger organisms are counted and removed. The remainder are then returned to the graduated tube and are diluted with water to a workable extent. The tube is then thoroughly shaken up so that a complete mixture or dissemination of the organisms through the fluid is effected. A graduated dipping tube about  $\frac{3}{16}$  of an inch bore, without any contraction at the end and capable of taking up  $\frac{1}{5}$  of a cubic centimetre, is quickly inserted into the mixture,  $\frac{1}{5}$  c.c. is taken up and is put on a glass slide. In this way at least five similar samples are withdrawn, care being taken to shake up the mixture afresh previous to every fresh dip. The samples thus obtained are then worked over under the microscope and all the species are identified and enumerated. The average of these countings is taken, and this is multiplied by the factor representing the amount of dilution—thus, if the sample is made up to 10 cubic centimetres, then the factor will be 50. The same method is employed in estimating the Diatoms and



other allied organisms, but in the case of these minuter forms several dilutions may be required before all the species can be estimated. The scarce forms are taken first, and after one or two further dilutions the numbers of the more abundant species are arrived at. In dealing with samples containing *Rhizosolenia* it was found necessary to dilute the collection to 5,000 cubic centimetres before the numbers in  $\frac{1}{5}$  c.c. could be counted. The examination of the Diatoms, &c., is carried out, under the microscope, with either a  $\frac{2}{3}$  inch English objective or a No. 3 Leitz objective (higher powers being used when necessary for the critical examination of any species), the  $\frac{1}{5}$  c.c. sample being passed very slowly backwards and forwards across the stage. In front of the worker there is a tray containing a number of empty glasses with names corresponding to the species that are usually found. A vessel containing small shot is placed close to the hand, and as the sample is passed under the objective of the microscope, each organism seen is recorded by placing one of the shot into the corresponding glass. When the examination is completed the shot in each glass is counted and the estimation made. This entire operation is repeated with at least five distinct dips from each gathering. This method of estimation was tested both against several dilutions of the one mixture, and also against actual countings of the organisms present, and the variation in all cases was found to be of practically no account. The bottle which originally contained the sample, and which was marked to show the height occupied by the organisms, is now placed under a graduated burette filled with water. The stopcock is opened and the water allowed to run into the bottle up to the mark exactly. The loss from the burette is read off and this represents the volume of the catch in cubic centimetres.

## DISCUSSION OF THE OBSERVATIONS.

The majority of the hauls discussed below were taken from the S.Y. "Ladybird" during the two critical periods of the year, spring (April) and late summer (August and September), when certain constituents in the plankton attain their maxima of development; while the other observations were taken throughout the year from smaller boats in the inshore waters of Port Erin Bay.

During the spring, a month (March 28th to April 27th) was devoted to this work from the "Ladybird," and in the 23 working days during that period we took in all 276 samples, an average of 12 per day.

In the summer and autumn (August 9th to September 20th) the "Ladybird" was again engaged on this work, and during this period 300 gatherings were taken in the 30 working days, an average of 10 per day. On one expedition (September 20th) 36 gatherings were taken in an afternoon, in a small area of only about two miles extent, as follows:—

LOCALITY A :—6 miles out, W.N.W. of Bradda, over 30 fms.

- |    |  |                                   |
|----|--|-----------------------------------|
| 1. | Hensen and Nansen nets let down to 30 fms. and hauled up | 10 fms. (30-20).                  |
| 2. | " " " " 20 fms. " "                                      | 10 fms. (20-10).                  |
| 3. | " " " " 10 fms. " "                                      | 10 fms. (10-0).                   |
| 4. | " " " " 30 fms. " "                                      | { open to } (30-0)<br>{ surface } |

Weighted open net (A) and two surface nets (A1 and A2) along with shear net (Sh. 1) at 15-20 fms.

Weighted open net (B) and two surface nets (B1 and B2) along with shear net (Sh. 2) at 7-8 fms.

(These each  $\frac{1}{2}$ -hour hauls; the one set taken immediately after the other).

Mill water bottle at 20 fms., strained at the time.

" " " " 20 fms., strained on shore.

LOCALITY B :—8 miles out W.N.W. of Bradda, over 30 fms.

- |    |  |                    |
|----|--|--------------------|
| 1. | Hensen and Nansen nets let down to 30 fms. and hauled up | 10 fms. (30-20).   |
| 2. | " " " " 20 fms. " "                                      | 10 fms. (20-10).   |
| 3. | " " " " 10 fms. " "                                      | 10 fms. (10-0).    |
| 4. | Nansen (alone) " " 30 fms. " "                           | to surface (30-0). |

Weighted open net (C) and 2 surface nets (C1 and C2) along with shear net (B1) at 7-8 fms.

Weighted open net (D) and 2 surface nets (D1 and D2) along with shear net (B2) at 15-20 fms.

(These each  $\frac{1}{2}$ -hour hauls; the one set taken immediately after the other).

Mill water bottle at 20 fms., at 10 fms., and at 5 fms.

The fixed stations at which observations were generally made are shown in the adjoining plan (fig. 1), where I and II indicate off-shore stations, respectively five and ten miles from land; and III, IV and V show the along-shore stations, one to the north towards Niarbyl, one to the south near the Calf Island, and one in the "southern sea" off Spanish Head—all, except II, in water of much the same depth, about 20 fathoms. The region covered measures about ten miles from east to west (out to sea) and rather less from north to south (along the coast), but the area investigated was really very much less, being confined to the above-mentioned stations from which plankton samples were taken and the in-shore waters of the Bay.

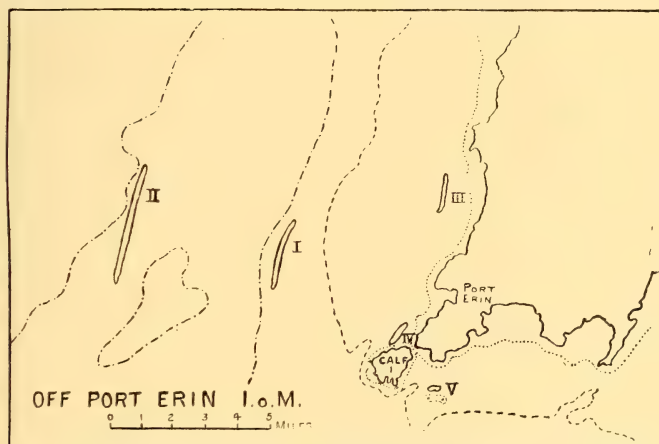


FIG. 1.—Plankton Stations off Port Erin.

The usual practice, in our work on the yacht, was this:—At each station, after taking the bearings, depth, &c., we first lowered two vertical nets, the Petersen-Hensen and the Nansen, to a depth of 20 fathoms, pulled them up slowly through 10 fathoms, and then closed them by "messengers" run down the line. This gave us

samples, taken vertically with these two very different nets, of the organisms present in the water between 10 and 20 fathoms. After that three ordinary horizontal open tow-nets exactly alike in all respects (size, shape, mesh, age) were put over—one (A) with a weight attached was allowed to sink to a depth of about 10 fathoms, from which it gradually rose as the ship went slowly ahead; while the other two (B and C), unweighted, remained continuously at or just under the surface and worked side by side like a pair of sharks or porpoises swimming in our wake. These two last nets ought, if there is any uniformity whatever in the plankton even in the most limited areas, to give similar results, and of course they did so in many cases. The purpose in taking the two similar surface nettings side by side was to show this, and also to test the reliability of the sample; for it was usually considered a more valid sample when these two nets agreed in their evidence. Where, under the circumstances stated above, the gatherings differed notably, there must have been some accident in the working of the nets or some irregularity in the distribution of the plankton, such as, no doubt, will sometimes be encountered when traversing the edge of a swarm of gregarious organisms; and it is important to get some evidence as to how frequently such accidents or irregularities may be met with. For example, on April 2nd, at along-shore Station III, the two surface-nets used together gave 17 c.c. and 42·5 c.c. of material respectively; on April 9th, at Station I, 2·5 and 8 c.c. respectively; and on April 24th, at Station II, they gave 7 c.c. and 15 c.c. respectively. On many occasions, of course, they were very similar, and on some almost identical in their catch (see examples given below). Each of these horizontal nets was hauled for 15 minutes.



The net A (which may be called the weight-net) is of use as having traversed a wider range, 0 to 10 fathoms, so as to sample all the water above the zone traversed by the vertical nets, and it frequently, and in fact usually, obtained a larger gathering and showed a greater variety of organisms than either the deeper, closing (vertical) or the open surface nets.

On some occasions, at the "along-shore" stations (e.g., 2 miles off Bradda Head) hauls were taken with a new "shear-net" made on the principle of the Heligoland "Scherbrutnetz" (*Conseil International—Rapports et Procès-verb.*, vol. ii, p. 62, 1904). This was used as a mid-water net—being lowered to a depth of 5 to 10 fathoms, where, through the action of the shearing plate, placed like a vertical otter-board, it remained even when the ship went ahead at a moderate speed, and so formed a most efficient instrument of capture in waters where the ordinary net cannot be towed. The mouth measured nine feet in circumference, the net was over ten feet in length, and being formed of rather coarse mesh caught quantities of the larger organisms of the plankton such as *Sagitta*, *Medusae*, *Ctenophora*, *Zoëas*, the larger *Copepoda* and some young fishes.

The variation in the bulk of the catch on different days with the same net, used so far as was possible under the same conditions, was very remarkable. The accompanying diagram shows graphically the range in quantity of the total catches with each kind of net during April, 1907. The Nansen net catches ranged in quantity from 0·5 c.c. to 164 c.c., the Petersen-Hensen from 0·5 c.c. to 64·5 cc., the weighted open tow-net from 5·5 c.c. to 41 c.c., the surface open tow-nets from 1 c.c. to 42·5 c.c., and the shear net from 11 cc. to 78·5 c.c. The black columns in the diagram (fig. 2) are drawn to scale,



and so give a true representation of the proportional bulk of the largest and smallest catches with each net.

We have considered it unnecessary to print in this first report the details of the nearly nine hundred tabular forms containing the results of the hauls, but we shall give various lists extracted from these tables, and curves derived from the lists, and we shall also reproduce a certain

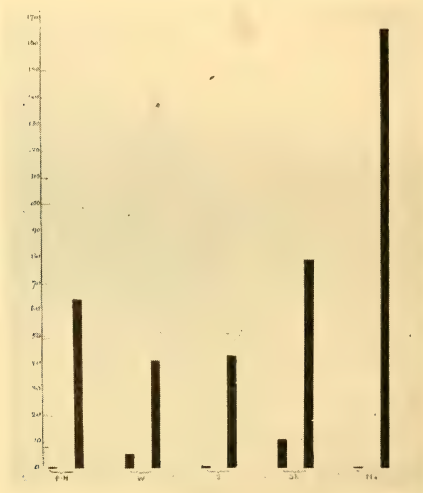


FIG. 2.—Showing by proportional columns the range in quantity taken by the various Plankton nets in April, 1907.

number of the sheets of records as samples of different nets, dates and localities. The complete series of sheets are deposited in the Zoological Department of the University of Liverpool and will be available for consultation there, and may possibly, if it be found desirable, be printed in a future report along with the results of a further year's work.

## TOTAL PLANKTON THROUGHOUT THE YEAR.

We give now, as the first summary statement from our Forms, and in further illustration of the great quantitative range shown by the gatherings taken on different days, the following record of the "total plankton," reduced to the average\* per haul for each individual day:—

Date.	Average per Haul.	Date.	Average per Haul.
Jan. 8	1.2 c.c.	April 25	10 c.c.
" 18	1 "	" 26	9 "
Feb. 5	1.2 "	" 27	10 "
" 22	2 "	May 8	11 "
" 26	0.5 "	" 18	5 "
Mar. 14	1.5 "	" 24	6 "
" 26	6 "	June 11	20 "
" 27	14.5 "	" 15	13.5 "
" 29	9 "	" 27	15 "
April 1	17 "	July 5	4 "
" 2	31 "	" 12	3.5 "
" 3	42.5 "	" 17	4.5 "
" 4	31 "	" 31	11 "
" 5	30 "	Aug. 9	14.5 "
" 6	34 "	" 10	25 "
" 8	23.5 "	" 12	12.5 "
" 9	15 "	" 13	4 "
" 10	17 "	" 14	18 "
" 11	21 "	" 15	18.5 "
" 13	25 "	" 16	12 "
" 15	13 "	" 17	13 "
" 16	11 "	" 19	12 "
" 17	51 "	" 20	12 "
" 18	14 "	" 21	4.5 "
" 19	17 "	" 22	6 "
" 22	13 "	" 23	3 "
" 23	22 "	" 24	18 "
" 24	16 "	" 26	5 "

\* We desire to point out that as the nets used were not all comparable, the vertical nets catching as a rule less and the shear net more than the open horizontal tow-nets, no conclusions are based solely on the details of this record. Moreover, during the greater part of the year, only open horizontal nets were used, while in spring and autumn, while the yacht was at work, the vertical nets and the shear net were used in addition. But as the number of observations is large, and the non-comparable nets more or less neutralise one another, the average per haul is probably a fair representation of the plankton caught. The averages may be lowered unduly by the vertical nets on some days, or raised too much by the shear net on others, but must be substantially correct for the weeks and months, and so the list serves to show the range in variation and the seasonal change—and that is all we use it for.

Date.	Average per Haul.	Date.	Average per Haul,
Aug. 27 .....	9.5 c.c.	Sept. 20 .....	5 c.c.
„ 28 .....	3 „	„ 21 .....	4.5 „
„ 29 .....	8 „	„ 23 .....	8.5 „
„ 30 .....	2 „	„ 24 .....	8 „
„ 31 .....	2 „	„ 26 .....	3 „
Sept. 2 .....	3 „	„ 27 .....	3 „
„ 3 .....	2 „	„ 28 .....	7 „
„ 4 .....	2 „	„ 30 .....	6 „
„ 5 .....	1.5 „	Oct. 1 .....	1.5 „
„ 6 .....	2 „	„ 9 .....	7 „
„ 9 .....	6 „	„ 14 .....	11.5 „
„ 10 .....	2 „	„ 24 .....	7 „
„ 11 .....	2.5 „	Nov. 4 .....	11 „
„ 12 .....	4 „	„ 8 .....	6 „
„ 13 .....	3 „	„ 16 .....	1.5 „
„ 14 .....	4.5 „	„ 25 .....	2.5 „
„ 16 .....	8 „	Dec. 12 .....	1 „
„ 17 .....	4 „	„ 20 .....	1 „
„ 18 .....	7 „	„ 23 .....	1 „
„ 19 .....	7 „	„ 30 .....	1.5 „

From this list and the unsmoothed curve shown below (fig. 8) it is seen that the greatest bulk of plankton in the water is in April, when the total catches in the day reached an average of 51 c.c. per haul. Other lesser elevations are seen in June with 20 c.c., and August with 25 c.c.

The catch in some individual hauls runs a great deal higher than these averages, the top score being the Nansen net on April 4th, with 164.5 c.c.

The spring maximum in the amount of the plankton is clearly due to a great and sudden increase in the amount of Diatoms present. The other rises seen later in the year, as in June, August, and to a slighter extent in October, are less marked, and are less clearly due to one cause.

#### SEASONAL VARIATIONS IN THE PLANKTON.

The above remarks indicate, what has in fact long been recognised, that the amount of plankton varies to some extent with the season.

We shall now reproduce some of our Forms giving the

results of hauls showing special features of the plankton at different times of the year.

Form No. **10**, representing the hauls taken on an off-shore station, on April 5th, shows the condition of affairs during the spring maximum of Diatoms. It will be noticed that 14 millions of one species, *Chaetoceros contortum*, were present in one haul of the Nansen net. The total number of Diatoms in that haul was nearly 17 millions, including two millions of *Thalassiosira nordenskiöldii*.

Comparatively few Copepoda and other large organisms were present. It will be noticed that the two surface gatherings of this date were moderately alike, the same organisms were present in both, although one net had, in some cases, about twice as many as the other; but still the hauls were of the same general type and the quantities were, in most cases, not very different, showing that one can get a good general idea of the fauna by such hauls, but that one cannot depend upon their being minutely representative. They may represent, apparently, something like double or half the quantity of organisms obtained in neighbouring hauls.

For comparison with Form **10** we print Form **71**, showing a similar series of hauls taken late in August from a neighbouring station. Here there are practically no Diatoms present, there being only a very few individuals of *Biddulphia mobiliensis*. On the other hand, the Copepoda are more abundant than they were in April. For example, compare *Oithona similis*, where only tens, amounting at most to a few hundreds, were present in April, and thousands (reaching eleven thousand in the weighted net) were in the August haul. Other interesting differences will be noticed on comparing the two Forms.



## 10.—Off-shore Station II, April 5th, 1907

Net used .....	Surface.	Surface.	Hensen.	Nansen.	Weight.
Depth in fathoms .....	0	0	20-10	20-10	10-0
Catch in c.cm. ....	9	12	12-5	100	15-5
<i>Asterionella bleakeleyi</i> .....	—	—	—	15,000	—
<i>Biddulphia mobiliensis</i> .....	3,000	4,000	1,000	15,000	7,000
<i>Chaetoceros contortum</i> .....	33,000	78,000	286,000	14,000,000	160,000
„ <i>decipiens</i> .....	6,000	6,000	6,000	50,000	10,000
„ <i>teres</i> .....	—	—	2,000	50,000	—
„ <i>diadema</i> .....	—	—	1,000	—	—
<i>Coscinodiscus concinnus</i> .....	2,000	4,000	1,000	15,000	2,000
<i>Coscinosira polychorda</i> .....	—	—	4,000	—	—
<i>Rhizosolenia semispina</i> .....	1,000	2,000	4,000	—	—
<i>Thalassiosira gravida</i> .....	1,000	1,000	8,000	90,000	—
„ <i>nordenskioldii</i> ...	21,000	52,000	26,000	2,000,000	70,000
<i>Lauderia borealis</i> .....	1,000	2,000	20,000	600,000	8,000
<i>Ceratulina bergonii</i> .....	—	—	1,000	—	—
<i>Ceratium furca</i> .....	—	1,000	1,000	—	2,000
„ <i>fuscus</i> .....	1,000	3,000	1,000	—	1,000
„ <i>tripos</i> .....	1,500	3,000	1,000	—	1,000
Medusoid gonophores .....	40	20	—	—	90
Plutei of Echinoderms .....	500	1,000	—	—	1,000
<i>Sagitta bipunctata</i> .....	—	—	—	—	6
Larval Polychæta .....	—	—	4	—	—
“ Mitraria ” .....	—	—	—	—	500
Crab zoea .....	—	—	1	6	5
Mysis stage of Crangon .....	—	—	—	—	1
Larval Nephrops 1st stage .....	—	—	—	—	3
<i>Evadne nordmanni</i> .....	15	10	—	—	—
<i>Calanus helgolandicus</i> .....	—	—	—	—	10
<i>Pseudocalanus elongatus</i> .....	35	40	16	250	220
<i>Temora longicornis</i> .....	10	30	3	225	130
<i>Centropages hamatus</i> .....	25	40	—	—	—
<i>Anomalocera pattersoni</i> .....	50	40	—	—	10
<i>Acartia clausi</i> .....	200	220	6	300	110
<i>Oithona similis</i> .....	20	10	7	200	30
Copepod nauplii .....	1,000	2,000	9,000	—	6,000
„ metanauplii .....	30	20	—	—	—
Barnacle nauplii .....	10	15	2	2	—
<i>Oikopleura</i> sp. ....	300	225	12	1,500	520
Fish eggs: Rockling .....	—	2	—	—	2
„ Scald fish .....	6	1	1	1	1
„ Plaice .....	1	—	—	—	—
„ Flounder .....	2	—	—	—	—
„ Long Rough Dab ...	—	1	—	—	—
„ Dab .....	—	3	—	—	—
„ Sail Fluke .....	—	2	—	—	—
„ Whiting .....	11	14	—	4	5
„ Haddock .....	2	—	—	1	2
„ Green Cod .....	5	6	—	5	5
„ Cod .....	13	12	—	4	2
„ Bib .....	—	3	—	1	—
Young fishes, Plaice .....	—	—	1	—	—

## 71.—Off-shore Station I, Aug. 21st, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Nansen	Weight
Depth in fathoms .....	0	0	20-10	20-0	20-10	10-0
Catch in c.cm. ....	1.5	7	0.5	2.5	2	8.5
Biddulphia mobiliensis .....	—	—	—	25	—	—
Ceratium furca .....	—	—	10	—	—	—
„ fusus .....	—	—	80	25	50	—
„ tripos .....	250	1,500	700	100	600	1,300
Peridinium sp. ....	—	—	30	50	25	—
Trochiscia sp. ....	—	—	10	—	—	—
Sagitta bipunctata .....	12	14	3	30	10	25
Tomopteris onisciformis .....	—	—	3	—	—	—
Larval Polychæta .....	100	100	—	—	—	—
Crab zoea .....	—	3	1	—	1	1
„ megalopa .....	—	—	—	—	—	1
Mysis stage of Crangon .....	1	—	1	3	6	10
Eurydice inermis .....	—	1	—	—	—	—
Nephrops 1st stage .....	—	—	1	—	2	—
Podon intermedium .....	10	40	—	20	10	50
Evadne nordmanni .....	—	—	—	—	—	15
Calanus helgolandicus .....	100	200	2	10	8	125
Pseudocalanus elongatus .....	60	30	50	300	375	550
Temora longicornis .....	25	40	5	65	40	100
Centropages hamatus .....	80	75	5	5	—	80
Anomalocera pattersoni .....	7	15	—	—	—	4
Acartia clausi .....	320	800	—	110	55	750
Oithona similis .....	2,200	8,000	125	1,000	500	11,000
Parapontella .....	6	10	—	5	—	—
Thaumaleus rigidus .....	—	—	—	—	1	—
Copepod nauplii. ....	10,000	30,000	750	2,000	1,350	15,000
„ juv. ....	2,600	5,000	240	500	500	2,000
Gasteropods, larval .....	—	—	—	25	—	—
Lamellibranchs, larval .....	—	—	10	50	25	—
Oikopleura sp. ....	360	200	6	500	—	200
Fish eggs, Goldsinny .....	1	—	—	—	—	—

In Form 66 we give the results of four hauls taken in Port Erin Bay about the middle of August (14th to 17th) to show again a plankton where Diatoms were absent, but where Copepods were present in abundance, amounting to 25,000 in the case of *Oithona similis* on August 17th. The three hauls of August 14th, 15th and 16th are very similar in total amounts, and not unlike in some of the constituent items, but the haul on August 17th showed nearly double the total quantity, due mainly

to the increase in one species of Copepod—*Oithona similis*. August 14th showed an unusually large number of Copepod Nauplii and of *Oikopleura*.

**66.**—Port Erin Bay. August 14,    15th,    16th,    17th.

Depth in Fathoms .....	0	0	0	0
Catch in c.cm. ....	18	18.5	17.5	30.5
Ceratium tripos .....	1,000	1,000	500	—
Pleurobrachia pileus .....	—	1	3	—
Medusoid gonophores .....	250	2	100	—
Sagitta bipunctata .....	600	1,800	800	700
Tomopteris onisciformis .....	—	25	6	—
"Mitraria" .....	100	—	—	—
Crab zoea .....	200	300	—	5
" megalopa .....	—	3	—	20
Mysis stage of Crangon .....	200	200	2	15
Podon intermedium .....	300	—	100	200
Evadne nordmanni .....	100	—	—	—
Calanus helgolandicus .....	50	700	500	700
Pseudocalanus elongatus .....	3,500	700	500	800
Temora longicornis .....	3,500	6,500	2,500	2,000
Centropages hamatus .....	100	200	200	200
Acartia clausi .....	1,000	600	100	200
Oithona similis .....	12,000	6,000	5,000	25,000
Caligus rapax .....	—	—	1	—
Paracalanus parvus .....	250	—	—	—
Copepod nauplii .....	25,000	13,000	3,500	13,000
" juv. ....	4,000	4,000	3,500	5,000
Lamellibranchs, larval .....	1,500	—	—	—
Oikopleura sp. ....	2,800	900	200	200
Fish eggs, Rockling .....	15	1	40	25
" Brill .....	—	—	—	1
" Goldsinny .....	—	1	—	—

In Form **104** we show an example of the Diatom fauna that makes its appearance again late in September. The two surface nets represented show very large numbers of Diatoms, extending up to 13 millions and 16 millions in single hauls in the case of *Rhizosolenia semispina*—in fact this highest peak in the September maximum of Diatoms is mainly composed of this one species of *Rhizosolenia*, whereas in the spring maximum the bulk of the catch, as may be seen from Form **10** (p. 200), is made up of *Chaetoceros contortum* and *Thalassiosira*

*nordenskioldii*, species that are rare or altogether absent in September gatherings. The genus *Thalassiosira* is mainly a spring form, rarely present after May, and is not represented in autumn in this year's results.

**104.**—Station III, September 12.

Depth in fathoms .....	0	0
Catch in c.cm. ....	10½	11
Asterionella bleakeleyi .....	1,200	1,200
Chaetoceros debile .....	1,000	3,000
„ decipiens .....	7,500	8,000
„ teres .....	20,000	60,000
„ subtile .....	123,000	140,000
Coscinodiscus concinnus ...	2,500	2,500
Ditylium brightwellii .....	2,500	2,500
Eucampia zodiacus .....	3,750	4,000
Melosira borreri .....	4,000	5,000
Lauderia borealis .....	100,000	120,000
Leptocylindrus sp.....	38,000	50,000
Coscinodiscus radiatus .....	1,250	1,250
Rhizosolenia semispina .....	13,000,000	16,000,000
„ shrubsolei .....	15,000	20,000
„ stolterfothii ...	25,000	30,000
„ setigera .....	2,500	2,500
„ alata .....	140,000	150,000
Ceratium furca .....	2,500	7,500
„ fusus .....	15,000	17,000
„ tripos .....	37,000	50,000
Medusoid gonophores .....	2	7
Calanus helgolandicus .....	5	11
Pseudocalanus elongatus ...	40	60
Centropages hamatus .....	8	20
Acartia clausi .....	800	900
Oithona similis .....	200	250
Isias clavipes .....	8	5
Parapontella brevicornis .....	1	1
Paracalanus parvus .....	20	80
Copepod nauplii.....	8,000	9,000
„ juv.....	3,000	3,800
Oikopleura sp. ....	10	10
Ascidian eggs .....	4,000	10,000

The three seasonal conditions illustrated by Forms **10** (April), **66** and **71** (August), and **104** (September) are very well marked, and a detailed examination of these series of hauls is instructive.



## COMPARISON OF HAULS.

The results which we print (Forms **17** and **18**) of the hauls obtained on April 9th and 10th in Port Erin Bay are good examples of a local plankton mainly composed of Diatoms. It will be noticed in running the eye down the groups in Form **17** that whereas the Diatoms occur in thousands extending up to even 100,000, the Dinoflagellates are in hundreds, extending, at most, to a thousand; the Copepoda are in tens, rarely reaching a hundred or two, while the fish-eggs are scattered units, such as 1 and 2. The general character of these hauls on April 9th, then, is that there are ten times as many Copepods as fish-eggs; ten times as many Dinoflagellates as Copepods, and ten times as many Diatoms as Dinoflagellates, per species. In Form **18**, on the following day, the proportions are somewhat the same; and if we pick out the largest numbers recorded in each of these groups they may be described in the case of each day as units, hundreds, thousands and tens of thousands.

	Diatoms	Dinoflagellates	Copepods	Fish Eggs
April 9	100,000	... 1,000	... 250	... 2
April 10	90,000	... 2,000	... 780	... 8

As another example of the same run of figures in these groups we note that in a surface haul, W. of the Calf Island, on March 29th, the total

Diatoms amount to	...	...	...	72,650
Dinoflagellates	„	...	...	3,500
Copepoda	„	...	...	363
Fish Eggs	„	...	...	93

Generally speaking these proportions hold good for many of the series of hauls not only in the Bay, but also outside; see, for example, Forms **20** and **21**, below.

It is also interesting to note that of these two series of hauls taken in exactly the same spot on adjoining days,

the total amount obtained is much the same, but is made up of rather different constituents, *Biddulphia mobiliensis*, *Chaetoceros contortum*, and some other forms, being more abundant on the 9th; while *C. debile*, present on the 9th, is altogether absent on the 10th. The very large number of Echinoderm Plutei on April 9th is noteworthy; their occurrence is very sporadic; they were present again in large numbers on April 19th, when 1,000 were taken in the haul corresponding to I. A. on April 9th. But, on the whole, the resemblance between the two hauls is more striking than the differences, the list of organisms is very nearly identical in the two sheets, and the general run of the numbers is for the most part the same.

Another interesting comparison, in this case of two separate but not distant localities taken practically at the same time, is seen in the Forms (20 and 21) that are given here for April 10th. No. 20 is from off-shore station I, five miles N.W. of Bradda Head, while No. 21 is from the second station ten miles off land along the same line. Both are in the open sea and at both the same set of nets (Hensen, Nansen, Weighted, and two Surface nets) were used, within an hour; but in the first locality the total bulk of the plankton caught was 104 c.c. while in the second locality it was only 39 c.c.; and it will be noticed in running the eye down the figures for the different organisms that the five-mile station yielded far more in the case of Diatoms and Dinoflagellates and fish-eggs, but less in the case of Copepoda. The total Diatoms amount to over  $3\frac{1}{2}$  millions at five miles as against 324,000 at ten miles; the total Dinoflagellates is 55,000 at five miles and 13,000 at ten miles; while the Copepods are under 3,000 at five miles and nearly 5,000 at ten miles. The general run of organisms present is the same in the two cases, although the total numbers differ so much.

## 17.—Port Erin Bay, April 9th, 1907.

Net used, Surface .....	I. A	II. A	I. B1	I. B2	I. B3	II. B1	II. B2
Catch in c.cm. ....	10·5	8	7	6·5	4	8·5	8·5
<i>Biddulphia mobiliensis</i> .....	45,000	7,000	8,500	2,500	3,000	7,500	2,500
<i>Chaetoceros contortum</i> ...	39,000	38,000	70,000	31,000	50,000	100,000	50,000
„ <i>debile</i> .....	9,000	—	2,000	—	2,500	2,000	—
„ <i>decipiens</i> ...	7,500	3,500	8,500	4,000	2,500	5,500	3,500
„ <i>teres</i> .....	1,500	—	1,000	—	1,000	—	500
„ <i>diadema</i> ...	2,000	—	2,500	1,000	1,000	500	1,500
„ <i>criophilum</i> .....	—	—	—	—	—	500	—
<i>Coscinodiscus concinnus</i> .....	3,000	2,000	2,000	1,000	2,000	3,500	—
<i>Ditylimum brightwellii</i> ...	—	—	500	—	250	1,000	—
<i>Rhizosolenia semispina</i> ...	500	1,000	1,000	2,000	1,000	3,000	1,700
<i>Thalassiosira gravida</i> ...	100	100	—	—	250	500	500
„ <i>nordenskioldii</i> .....	12,000	13,000	5,000	14,000	11,000	30,000	17,000
„ <i>subtilis</i> .....	1,000	6,000	6,000	4,000	5,000	5,500	4,000
<i>Lauderia borealis</i> .....	2,500	500	2,500	500	500	3,000	750
<i>Trochiscia</i> sp.....	—	—	—	—	20	25	25
<i>Acanthometra</i> sp.....	—	—	—	—	50	50	—
<i>Ceratium furca</i> .....	300	—	500	—	250	200	500
„ <i>fuscus</i> .....	100	1,000	500	1,000	500	1,000	1,000
„ <i>tripos</i> .....	—	1,000	500	—	500	250	500
<i>Peridinium</i> sp. ....	—	1,000	500	100	250	300	500
Medusoid Echinophores ...	75	70	10	27	30	30	20
Plutei of Echinoderms .....	1,000	1,500	500	500	500	—	—
Larval Polychaeta.....	75	75	20	10	30	50	30
“Mitraria” .....	100	100	—	—	100	100	100
Crab zoea .....	5	—	—	1	—	1	—
<i>Podon intermedium</i> .....	20	12	10	10	20	—	10
<i>Evadne nordmanni</i> .....	5	—	—	—	—	50	—
<i>Calanus helgolandicus</i> ...	25	6	10	10	10	15	10
<i>Pseudocalanus elongatus</i> ..	70	175	150	250	190	125	140
<i>Temora longicornis</i> .....	20	35	20	5	5	45	20
<i>Centropages hamatus</i> ...	—	—	5	5	5	10	10
<i>Acartia clausi</i> .....	60	40	10	40	15	60	45
<i>Oithona similis</i> .....	140	85	55	40	35	100	70
<i>Anomalocera</i> juv. ....	—	2	—	—	10	—	—
<i>Paracalanus parvus</i> .....	—	—	—	15	—	—	—
Copepod nauplii .....	11,000	3,000	3,000	1,500	4,500	3,000	2,000
„ metanauplii ...	—	20	—	—	—	—	—
„ juv. ....	1,100	375	160	475	165	400	300
Barnacle nauplii .....	400	175	75	275	220	140	180
„ cypris stage ...	10	6	6	12	7	5	1
<i>Oikopleura</i> sp. ....	900	600	550	700	630	750	680
Fish Eggs:—Rockling...	1	1	—	2	—	—	—
Com. Dragonet .....	2	1	—	—	1	—	—
Cod .....	1	1	—	—	—	—	—
Green Cod .....	1	—	—	—	—	2	—
Bib .....	1	—	—	—	—	—	—
Whiting .....	2	—	—	1	—	1	1
Red Gurnard .....	—	1	—	—	—	—	—
Topknot .....	2	—	—	—	—	—	—
Dab .....	1	1	—	—	—	—	—
Sail Fluke .....	1	—	—	—	—	—	—
Sprat .....	—	1	—	1	—	1	—
Young Fishes—							
Larval Gadoid .....	—	—	1	—	—	—	—
Larval Pleuronectid ...	—	—	—	—	—	1	—

## 18.—Port Erin Bay, April 10th, 1907.

Net used, Surface .....	I.A1	II.A	I.B1	I.B2	I.B3	II.B1	II.B2
Catch in c.cm. ....	14	8	7	8	8	10.5	12.5
<i>Biddulphia mobiliensis</i> .....	5,000	1,500	1,500	500	3,000	1,500	4,000
<i>Chaetoceros contortum</i> .....	15,000	20,000	20,000	15,000	50,000	90,000	20,000
„ <i>decipiens</i> ...	2,000	—	1,000	2,000	5,000	6,000	—
„ <i>teres</i> .....	—	—	500	500	500	500	—
„ <i>diadema</i> ...	—	150	—	—	1,500	500	—
<i>Coscinodiscus concinnus</i> .....	2,000	1,000	1,500	500	2,000	500	1,000
<i>Eucampia zodiacus</i> .....	—	—	—	—	200	—	—
<i>Rhizosolenia semispina</i> .....	500	—	500	500	3,500	1,000	1,000
<i>Thalassiosira gravida</i> ...	—	—	—	—	500	500	—
„ <i>nordenskioldii</i> .....	3,500	10,000	4,000	4,000	32,000	28,000	6,000
„ <i>subtilis</i> .....	8,000	6,000	3,000	2,000	6,000	9,000	4,000
<i>Lauderia borealis</i> .....	500	250	—	500	4,000	1,000	500
<i>Trochiscia</i> , sp. ....	—	50	—	—	—	—	—
<i>Acanthometra</i> sp. ....	30	—	150	—	50	25	—
<i>Ceratum furca</i> .....	—	—	100	—	250	250	150
„ <i>fuscus</i> .....	1,500	250	500	—	250	500	200
„ <i>tripos</i> .....	200	500	2,000	—	250	500	250
<i>Peridinium</i> sp. ....	500	100	500	500	500	1,000	150
Medusoid gonophores ...	150	3	60	70	50	15	180
Plutei of Echinoderms .....	100	100	—	—	250	500	—
<i>Sagitta bipunctata</i> .....	—	—	—	—	—	2	—
Larval Polychaeta .....	150	5	60	—	50	—	120
“Mitraria” .....	200	150	50	—	100	—	200
Crab zoea .....	—	—	—	—	1	—	5
Mysis stage of Crangon .....	5	—	3	—	1	—	—
Podon intermedium .....	20	—	10	30	—	—	15
<i>Evadne nordmanni</i> .....	10	2	20	20	10	—	15
<i>Calanus helgolandicus</i> ...	60	30	100	30	35	—	60
<i>Pseudocalanus elongatus</i> .....	780	30	300	150	50	35	480
<i>Temora longicornis</i> .....	100	30	70	50	60	35	100
<i>Centropages hamatus</i> ...	20	10	30	4	10	—	15
<i>Acartia clausi</i> .....	70	30	80	50	150	30	90
<i>Oithona similis</i> .....	350	100	200	100	250	300	200
<i>Anomalocera</i> juv. ....	—	10	10	—	—	25	—
<i>Paracalanus parvus</i> .....	—	—	—	—	—	—	60
Copepod nauplii .....	11,500	500	2,500	3,500	500	1,000	12,000
„ juv. ....	2,250	75	750	900	350	100	2,000
Barnacle nauplii .....	850	50	460	270	150	10	1,230
„ cypris stage .....	12	4	8	10	2	1	10
<i>Oikopleura</i> sp. ....	1,800	250	1,300	950	700	230	2,000
Fish Eggs—Rockling ...	1	6	—	—	1	8	—
Common Dragonet ...	—	—	1	—	—	1	—
Cod .....	1	—	—	—	1	1	1
Green cod .....	—	2	1	—	1	1	—
Bib .....	1	1	—	1	3	—	—
Whiting .....	2	—	—	—	—	3	—
Flounder .....	—	—	—	—	—	3	—
Dab .....	—	—	—	—	—	1	—
Long rough dab .....	—	—	—	—	—	—	1
Sail fluke .....	—	—	—	—	—	—	1
Sprat .....	—	—	—	—	1	—	—
Young Fishes—							
Pleuronectid .....	1	—	—	—	—	—	—



**20.**—Off-shore Station I, April 10th, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Weight
Depth in fathoms .....	0	0	20-10	20-10	10-0
Catch in c.cm. ....	12	18·5	1	58·5	15
<i>Biddulphia mobiliensis</i> .....	5,000	5,000	500	1,000	7,000
<i>Chaetoceros contortum</i> .....	39,000	28,000	19,000	1,200,000	26,000
" <i>debile</i> .....	—	—	—	75,000	—
" <i>decipiens</i> .....	2,000	1,000	500	62,000	2,000
" <i>sociale</i> .....	—	—	4,500	75,000	—
" <i>teres</i> .....	—	—	1,000	25,000	1,000
" <i>diadema</i> .....	—	—	—	25,000	—
<i>Coscinodiscus concinnus</i> .....	1,000	1,500	500	12,000	1,000
<i>Ditylium brightwellii</i> .....	—	—	—	6,000	—
<i>Eucampia zodiacus</i> .....	—	150	—	—	—
<i>Rhizosolenia semispina</i> .....	1,000	—	—	12,000	1,000
<i>Thalassiosira gravida</i> .....	—	—	500	12,000	—
" <i>nordenskioldii</i> ...	58,000	135,000	15,000	1,600,000	17,000
" <i>subtilis</i> .....	3,000	1,500	—	12,000	10,000
<i>Lauderia borealis</i> .....	1,000	1,500	5,000	150,000	—
<i>Ceratium furca</i> .....	—	1,000	—	—	—
" <i>fuscus</i> .....	3,000	500	—	—	1,000
" <i>tripos</i> .....	4,000	3,000	500	—	3,000
<i>Peridinium</i> sp. ....	1,000	1,000	—	37,000	500
Medusoid gonophores .....	30	80	5	26	80
Plutei of <i>Echinoderms</i> .....	1,000	1,000	—	—	500
<i>Sagitta bipunctata</i> .....	—	—	—	—	6
<i>Tomopteris onisciformis</i> .....	—	—	—	1	2
Larval <i>Polychaeta</i> .....	—	—	—	20	20
Crab zoea .....	2	1	—	—	6
Mysis stage of <i>Crangon</i> .....	—	—	—	1	14
Nephrops, 1st stage .....	—	—	—	3	5
Podon intermedium .....	—	—	1	—	10
<i>Evadne nordmanni</i> .....	10	10	—	—	10
<i>Calanus helgolandicus</i> .....	25	1	3	23	20
<i>Pseudocalanus elongatus</i> .....	—	—	18	130	350
<i>Temora longicornis</i> .....	25	—	5	56	180
<i>Centropages hamatus</i> .....	30	40	—	2	10
<i>Acartia clausi</i> .....	500	500	8	14	200
<i>Oithona similis</i> .....	—	30	2	47	40
<i>Anomalocera</i> juv. ....	170	500	—	—	20
Copepod nauplii .....	3,000	2,000	500	—	5,000
" <i>metanauplii</i> .....	—	—	—	—	100
"    juv. ....	500	—	25	130	600
Barnacle nauplii .....	10	10	2	25	20
"    cypris stage .....	2	1	—	1	5
<i>Oikopleura</i> sp. ....	270	300	18	80	350
Fish Eggs: Haddock .....	4	—	—	—	1
Cod .....	5	31	—	—	5
Green Cod .....	15	33	—	—	22
Com. Dragonet .....	5	3	—	—	1
Whiting .....	60	89	—	—	16
Rockling .....	—	1	—	—	—
Grey Gurnard .....	—	6	—	—	—
Bib .....	3	23	—	—	6
Topknot .....	1	3	—	—	1
Brill .....	1	—	—	—	—
Red Gurnard .....	1	—	—	—	—
Sail Fluke .....	9	2	—	—	1
Dab .....	2	4	—	—	1
Scald fish .....	3	1	—	—	—
Long Rough Dab .....	—	1	—	—	1
Sprat .....	3	6	—	—	4
Young fishes—Gadoid .....	—	—	—	1	10

## 21.—Off-shore Station II, April 10th, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Weight
Depth in fathoms .....	0	0	20-10	20-10	10-0
Catch in c.cm. ....	7	8.5	2.5	9	12
<i>Asterionella bleakeleyi</i> .....	—	—	100	—	—
<i>Biddulphia mobiliensis</i> .....	100	100	100	250	—
<i>Chaetoceros contortum</i> .....	1,000	4,000	12,000	180,000	2,000
„ <i>decipiens</i> .....	—	—	2,000	11,000	—
„ <i>sociale</i> .....	—	—	100	5,000	—
„ <i>teres</i> .....	—	—	—	4,000	—
<i>Coscinodiscus concinnus</i> .....	2,000	1,000	100	1,000	1,000
<i>Ditylium brightwellii</i> .....	—	—	—	1,000	—
<i>Eucampia zodiacus</i> .....	—	—	—	500	—
<i>Rhizosolenia semispina</i> .....	—	—	100	1,000	—
„ <i>stolterfothii</i> .....	—	—	—	100	—
<i>Thalassiosira gravida</i> .....	—	—	50	1,000	—
„ <i>nordenskioldii</i> .....	1,500	3,500	10,000	58,000	1,000
„ <i>subtilis</i> .....	1,000	—	50	5,000	2,000
<i>Lauderia borealis</i> .....	100	—	1,500	9,000	—
<i>Ceratulina bergonii</i> .....	—	—	—	250	—
<i>Ceratium furca</i> .....	500	100	1,000	—	—
„ <i>fuscus</i> .....	200	500	500	—	—
„ <i>tripos</i> .....	1,000	500	500	1,000	1,000
<i>Peridinium</i> sp. ....	500	1,000	500	3,000	2,000
Medusoid gonophores .....	40	10	—	16	150
Plutei of Echinoderms .....	—	—	100	500	1,000
<i>Sagitta bipunctata</i> .....	—	—	—	6	24
<i>Tomopteris onisciformis</i> .....	—	—	—	1	2
Larval Polychaeta .....	—	—	—	20	—
“Mitraria” .....	150	—	50	—	1,000
Mysis stage of Crangon .....	—	—	—	5	6
Podon intermedium .....	—	—	1	—	—
<i>Evadne nordmanni</i> .....	10	—	—	—	—
<i>Calanus helgolandicus</i> .....	6	2	3	36	150
<i>Pseudocalanus elongatus</i> .....	—	—	3	240	450
<i>Temora longicornis</i> .....	10	30	4	30	200
<i>Centropages hamatus</i> .....	10	10	—	—	—
<i>Acartia clausi</i> .....	880	570	2	15	62
<i>Oithona similis</i> .....	30	100	2	115	375
<i>Anomalocera</i> juv. ....	500	750	—	—	400
Copepod nauplii .....	1,500	2,000	1,000	3,000	5,000
„ metanauplii .....	36	150	—	20	350
„ juv. ....	360	500	10	500	250
Barnacle nauplii .....	10	40	5	60	330
„ cypris stage .....	3	5	1	3	25
<i>Oikopleura</i> sp. ....	1,360	1,800	22	400	1,000
Fish Eggs—					
Whiting .....	16	13	—	—	—
Red Gurnard .....	8	5	—	—	1
Green Cod .....	12	7	—	—	1
Cod .....	—	6	—	—	1
Bib .....	2	—	—	—	—
Scald fish .....	1	1	3	2	5
Dab .....	3	1	—	—	—
Sprat .....	—	—	—	1	—
Young fishes—Gadoid .....	—	—	—	—	5

As representative examples of the series of hauls taken at the two offshore stations (I and II) early in April we give here copies of our Forms **10** and **12**. These are both localities in the open sea, well out from the land, about five miles apart, and under, so far as can be seen, practically the same influences and conditions. They exemplify several points we wish to elaborate, viz., a certain amount of similarity between the surface hauls, the weighted net at ten fathoms showing as a rule a larger catch than the surface nets, and the Nansen vertical bringing up more than the Hensen. But the point we specially wish to illustrate from these Forms is that the plankton fauna on these two occasions had a similar character, although the numerical results may be far from agreeing. The total Diatoms at Station I are over twelve millions and at Station II over seventeen; in each case it is the Nansen net that caught the millions both of *Chaetoceros* and of *Thalassiosira*. The total Copepoda at Station I is 1,534 and at Station II 2,247, but the numbers in the case of some of the species are of the same "order" on the two Forms—*Calanus* is in units, *Centropages* and *Anomalocera* in tens and *Acartia* in hundreds in each case.

Finally, the conclusion one comes to from the inspection of these Forms is that much the same organisms are present in somewhat similar proportions; so that although it is possible to discuss the general character of the fauna and the relative abundance of different groups, it is not possible to use the numbers as the basis of calculations as to the quantity of any group, or of living things as a whole, in any large area of the sea at a particular time—the results arrived at might easily be 50 per cent. wrong in either direction.

To show—what will be readily admitted by all who

## 10.—Station II, April 5th, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Weight
Depth in fathoms .....	0	0	20-10	20-10	10-0
Catch in c.cm. ....	9	12	12.5	100	15.5
Asterionella bleakeleyi .....	—	—	—	15,000	—
Biddulphia mobiliensis .....	3,000	4,000	1,000	15,000	7,000
Chaetoceros contortum .....	33,000	78,000	286,000	14,000,000	160 000
„ decipiens ...	6,000	6,000	6,000	50,000	10,000
„ teres .....	—	—	2,000	50,000	—
„ diadema ...	—	—	1,000	—	—
Coscinodiscus concinnus .....	2,000	4,000	1,000	15,000	2,000
Coscinosira polychorda... ..	—	—	4,000	—	—
Rhizosolenia semispina .....	1,000	2,000	4,000	—	—
Thalassiosira gravida ...	1,000	1,000	8,000	90,000	—
„ nordenskioldii .....	21,000	52,000	26,000	2,000,000	70,000
Lauderia borealis .....	1,000	2,000	20,000	600,000	8,000
Ceratulina bergonii .....	—	—	1,000	—	—
Ceratum furca .....	—	1,000	1,000	—	2,000
„ fusus .....	1,000	3,000	1,000	—	1,000
„ tripos .....	1,500	3,000	1,000	—	1,000
Medusoid gonophores ...	40	20	—	—	90
Plutei of Echinoderms .....	500	1,000	—	—	1,000
Sagitta bipunctata .....	—	—	—	—	6
Larval Polychaeta .....	—	—	4	—	—
'Mitraria' .....	—	—	—	—	500
Crab zoea .....	—	—	1	6	5
Mysis stage of Crangon .....	—	—	—	—	1
Larval Nephrops, stage 1 .....	—	—	—	—	3
Evadne nordmanni .....	15	10	—	—	—
Calanus helgolandicus ...	—	—	—	—	10
Pseudocalanus elongatus .....	35	40	16	250	220
Temora longicornis .....	10	30	3	225	130
Centropages hamatus ...	25	40	—	—	—
Anomalocera pattersoni .....	50	40	—	—	10
Acartia clausi .....	200	220	6	300	110
Oithona similis .....	20	10	7	200	30
Copepod nauplii .....	1,000	2,000	9,000	—	6,000
„ metanauplii ...	30	20	—	—	—
Barnacle nauplii .....	10	15	2	2	—
Oikopleura sp. ....	300	225	12	1,500	520
Fish eggs :—					
Rockling .....	—	2	—	—	2
Scald fish .....	6	1	1	1	1
Plaice .....	1	—	—	—	—
Flounder .....	2	—	—	—	—
Long Rough Dab ...	—	1	—	—	—
Dab .....	—	3	—	—	—
Sailfluke .....	—	2	—	—	—
Whiting .....	11	14	—	4	5
Haddock .....	2	—	—	1	2
Green Cod .....	5	6	—	5	5
Cod .....	13	12	—	4	2
Bib .....	—	3	—	1	—
Young fishes :—					
Plaice ... ..	—	—	1	—	—



## 12.—Station I, April 8th, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Weight
Depth in fathoms .....	0	0	20-10	20-10	10-0
Catch in c.cm. ....	20	12	6·5	73	21
<i>Asterionella bleakeleyi</i> .....	100	—	—	—	—
<i>Biddulphia mobiliensis</i> .....	100	4,000	300	20,000	2,000
<i>Chaetoceros contortum</i> .....	12,000	10,000	31,000	1,650,000	9,000
„ <i>debile</i> .....	156,000	60,000	100,000	7,500,000	138,000
„ <i>decipiens</i> ...	9,000	10,000	4,000	150,000	27,000
„ <i>sociale</i> .....	—	—	6,000	—	—
„ <i>teres</i> .....	—	—	1,000	—	—
<i>Coscinodiscus concinnus</i> .....	800	3,000	1,000	50,000	1,000
<i>Coscinosira polychorda</i> ...	—	—	—	20,000	—
<i>Ditylimum brightwellii</i> ...	100	—	—	—	—
<i>Rhizosolenia semispina</i> .....	100	—	—	—	—
<i>Thalassiosira gravida</i> ...	—	—	1,000	50,000	—
„ <i>nordenskioldii</i> .....	186,000	120,000	37,000	1,350,000	132,000
„ <i>subtilis</i> ...	15,000	15,000	—	—	20,000
<i>Lauderia borealis</i> .....	100	—	7,000	450,000	3,000
<i>Leptocylindrus danicus</i> ...	—	—	—	1,000	—
<i>Ceratium furca</i> .....	100	500	—	—	300
„ <i>fuscus</i> .....	100	500	—	—	500
„ <i>tripos</i> .....	100	500	250	—	500
Medusoid gonophores ...	—	—	—	8	100
Plutei of Echinoderms .....	—	—	—	—	100
<i>Sagitta bipunctata</i> .....	—	—	—	2	10
Larval Polychaeta .....	—	—	3	3	10
Crab zoea .....	1	—	—	—	4
Mysis stage of Crangon .....	—	—	2	2	—
Larval Nephrops, stage 1 .....	—	—	—	—	2
<i>Evadne nordmanni</i> .....	50	75	—	—	—
<i>Calanus helgolandicus</i> ...	1	2	1	3	1
<i>Pseudocalanus elongatus</i> .....	—	—	9	40	500
<i>Temora longicornis</i> .....	10	—	6	30	200
<i>Centropages hamatus</i> ...	6	40	—	—	—
<i>Anomalocera pattersoni</i> .....	25	75	—	—	—
<i>Acartia clausi</i> .....	225	200	1	—	100
<i>Oithona similis</i> .....	14	—	1	4	30
<i>Isias clavipes</i> .....	—	—	—	—	10
Copepod nauplii .....	500	—	500	1,000	—
„ metanauplii ...	100	75	3	—	—
„ juv. ....	50	—	—	—	—
Barnacle nauplii .....	10	15	2	20	150
„ cypris stage .....	10	—	2	—	4
<i>Oikopleura</i> sp. ....	100	50	6	6	350
Ascidian eggs .....	—	100	—	—	—
Fish eggs :—Rockling ...	—	1	—	—	—
Common Dragonet .....	—	1	—	—	1
Sailfluke .....	5	1	—	—	3
Topknot .....	—	2	—	—	—
Long Rough Dab ...	1	—	—	—	—
Dab .....	1	—	—	—	—
Scald fish .....	1	—	—	—	—
Cod .....	6	27	—	—	6
Whiting .....	29	47	—	—	10
Bib .....	12	24	—	—	—
Young fishes :—Gadoid...	—	—	—	1	—

have had any experience of plankton work—the marked effect of the size and mesh of the net upon the resulting catch, we give here from Form **47** the hauls of two surface nets and a shear net taken off Bradda Head on April 23rd; and we add also another shear-net haul taken later the same day a couple of miles off, between Bradda Head and the Calf Island. It will be noticed that the two surface hauls are very much alike in quantity and constitution, and the two shear-net hauls are like one another and very different from the surface hauls. The shear-net has retained no Diatoms and no Dinoflagellates, but has caught far larger quantities of the larger organisms, such as Medusoids (*Hybocodon prolifer*) 4,500 against 10 and 100 taken in the surface nets at the same time, Sagitta 200 against 2, young Shrimps 1,800 against 5 and 8, and young Norway Lobsters 1,600 against 1. In the case of the Copepoda the shear-nets have large hauls of a large form such as *Calanus*, but much smaller hauls of the smaller forms such as *Acartia* and *Oithona*. Similarly the shear-nets have not retained the larval and young Copepods, but have most of the fish eggs and all the young fishes. Some of the differences in further detail may be due to the depth at which the shear-net was towed, but the broad lines of difference are clearly seen to be caused by the nature of the nets.

In order to determine more definitely, without any disturbing influence due to depth, the difference in catching power between the large open-meshed shear-net and the much smaller ordinary tow-net made of fine-meshed silk, we tied a tow-net to the frame of the shear-net so that the two would work together side by side, and we show here in Form **105** the results of two such double hauls.

In the first place, it will be noticed that the shear-net

**47.**—One mile W. of Bradda Head, April 23rd, 1907.

Shear\* = Calf Island to Bradda.

Net used .....	Surface	Surface	Shear	Shear*
Depth in fathoms .....	0	0	10	10
Catch in c.cm. ....	12·5	13	75·5	78
<hr/>				
<i>Biddulphia mobiliensis</i> .....	—	500	—	—
<i>Coscinodiscus concinnus</i> .....	500	500	—	—
<i>Peridinium</i> sp. ....	500	1,000	—	—
<i>Pleurobrachia pileus</i> .....	—	—	4	—
Medusoid gonophores .....	10	100	4,500	240
<i>Sagitta bipunctata</i> .....	—	2	200	400
<i>Tomopteris onisciformis</i> .....	—	—	—	3
Larval <i>Polychaeta</i> .....	50	50	440	—
' <i>Mitraria</i> ' .....	100	100	—	—
Crab zoea .....	6	3	280	1,600
Mysis stage of Crangon .....	5	8	1,800	1,900
Nephrops, 1st stage .....	1	—	1,600	600
<i>Evadne nordmanni</i> .....	100	50	—	—
<i>Calanus helgolandicus</i> .....	1,500	1,250	4,000	13,480
<i>Pseudocalanus elongatus</i> ...	300	200	480	240
<i>Temora longicornis</i> .....	250	300	560	2,300
<i>Centropages hamatus</i> .....	50	100	40	—
<i>Anomalocera pattersoni</i> .....	10	100	40	60
<i>Acartia clausi</i> .....	8,000	6,200	120	1,000
<i>Oithona similis</i> .....	2,350	2,200	40	—
<i>Metridia lucens</i> .....	—	—	20	3
<i>Candacia armata</i> .....	—	—	2	—
Copepod nauplii .....	8,500	11,500	—	—
„ juv. ....	2,000	2,000	—	—
Barnacle nauplii .....	—	—	1,000	360
„ cypris stage .....	43	280	10	—
<i>Oikopleura</i> sp. ....	700	1,000	1,000	—
Fish eggs:—				
Rockling .....	12	17	36	60
Whiting .....	4	16	32	15
Cod .....	2	4	18	8
Green Cod .....	3	8	10	10
Bib .....	3	9	37	20
Grey Gurnard .....	—	—	8	4
Dragonet .....	4	2	10	6
Haddock .....	—	—	4	3
Top-knot .....	—	—	8	—
Dab .....	3	1	3	2
Sprat .....	2	4	6	6
Young fishes:—				
Gadoid .....	—	—	30	70
Larval Gadoid .....	—	—	—	7
Sand-eel .....	—	—	—	1
Post-larval Agonus .....	—	—	—	1

## 105.—Mid-Channel, September 12th, 1907.

Net used .....	Shear A	Tow-net A	Shear B	Tow-net B
Depth in fathoms .....	10	10	20	20
Catch in c.cm. ....	18.5	11	13.5	2
<hr/>				
<i>Biddulphia mobiliensis</i> .....	—	—	—	130
<i>Chaetoceros contortum</i> .....	—	—	—	1,250
„ <i>debile</i> .....	—	—	—	3,700
„ <i>decipiens</i> .....	—	3,000	20	3,500
„ <i>sociale</i> .....	—	—	—	750
„ <i>teres</i> .....	—	7,500	—	23,000
„ <i>convolutum</i> .....	—	—	—	1,300
„ <i>densum</i> .....	—	2,000	—	1,500
„ <i>diversum</i> .....	—	—	—	400
„ <i>subtile</i> .....	—	13,500	—	5,000
<i>Coscinodiscus concinnus</i> .....	—	500	—	600
„ <i>radiatus</i> .....	—	4,500	—	4,000
<i>Ditylium brightwellii</i> .....	—	—	—	120
<i>Eucampia zodiacus</i> .....	—	500	—	130
<i>Rhizosolenia semispina</i> .....	—	80,000	500	165,000
„ <i>shrubslei</i> .....	—	500	50	625
„ <i>alata</i> .....	—	—	—	3,400
„ <i>stolterfothii</i> .....	—	500	—	1,500
„ <i>setigera</i> .....	—	250	—	—
<i>Lauderia borealis</i> .....	—	500	—	1,000
<i>Leptocylindrus danicus</i> .....	—	—	—	600
<i>Asterionella japonica</i> .....	—	—	—	120
<i>Ceratium fusus</i> .....	—	500	50	250
„ <i>tripos</i> .....	10	5,000	50	3,000
<i>Peridinium</i> sp. ....	—	500	—	120
<i>Trochiscia</i> sp. ....	—	100	20	—
Medusoid gonophores ...	45	1	55	3
<i>Sagitta bipunctata</i> .....	200	5	135	1
Larval Polychaeta .....	25	1,500	—	250
'Mitraria' .....	—	2,000	—	120
Crab zoea .....	2	1	—	—
Mysis stage of Crangon .....	2	—	—	1
<i>Microniscus calani</i> .....	70	—	10	—
<i>Calanus helgolandicus</i> .....	2,600	110	275	20
<i>Pseudocalanus elongatus</i> ...	300	33,600	285	6,250
<i>Temora longicornis</i> .....	10	—	2	1
<i>Centropages hamatus</i> .....	6	5	3	2
<i>Acartia clausi</i> .....	350	3,640	450	200
<i>Oithona similis</i> .....	60	2,840	65	1,200
<i>Microcalanus pusillus</i> .....	10	200	10	2,500
<i>Paracalanus parvus</i> .....	—	100	20	160
Copepod nauplii .....	30	24,000	75	—
„ juv. ....	60	12,500	275	—
Gasteropods, larval .....	10	1,000	—	500
Lamellibranchs, „ .....	—	1,000	—	370
<i>Oikopleura</i> sp. ....	25	1,000	50	140
Ascidian eggs .....	25	1,500	25	600



A and its tow-net at about 10 fathoms caught nearly twice as much material as the same two nets (B) worked at about 20 fathoms.

The further point is that in each case the tow-net retained the Diatoms, the Dinoflagellates, the minute larval forms and the smaller Copepoda which had escaped the shear-net, while the latter caught more of the larger organisms, such as Medusae, *Sagitta*, *Microniscus*, and the large Copepod *Calanus*. The number of organisms in the tow-net in each case is enormously greater, but those in the shear-net bulk larger on account of their individual size.

Taking the last item on the lists as an example, the obvious explanation of the numbers would be that there were more Ascidian eggs at 10 fathoms than at 20, and therefore tow-net A caught more than tow-net B; no doubt both shear-nets being so much larger caught still more, but the majority of the eggs passed through the wide meshes, and only a very few (25) were retained accidentally in each case, probably through being entangled in the appendages of larger crustacea or through the blocking up of some of the meshes.

#### THE SURFACE NETS.

The two ordinary open tow-nets with a mouth diameter of  $14\frac{1}{2}$  inches, and made of silk No. 9, with 94 threads to the inch, were towed side by side on the surface of the sea about 50 feet behind the ship for fifteen minutes on each occasion. In the great majority of cases it may be certain that their catch was limited to the upper two feet of the sea; and yet notwithstanding the uniformity of the conditions the results were in many cases very different. The following list shows the bulk of the catches on the various occasions when the two nets were

used together, and although some show identical results, as on April 15th, 19th, 22nd, August 21st, 24th, 27th, September 6th and 20th, and in other cases amounts which are very nearly the same, such as 16 c.c. and 15.5 c.c. on April 13th and April 19th, 9 c.c. and 9.5 c.c. on April 16th, 10.5 and 11 c.c. on September 12th, &c.; still other cases are very different, such as 14 and 1, 8 and 2.5, 17 and 42.5, 1.5 and 7 c.c. respectively.

April	Net B	Net C	Aug.	Net B	Net C
	1—8 c.c. ...	25 c.c.		21—1.5 c.c....	7
	2—17 ...	42.5		21—3 ...	3
	4—14 ...	1		23—9 ...	6.5
	5—9 ...	12		23—4.5 ...	4
	8—20 ...	12		23—5 ...	2
	9—8 ...	2.5		24—2 ...	1.5
	9—9 ...	11.5		24—2 ...	2
	10—12 ...	18.5		26—1 ...	2
	10—7 ...	8.5		27—1 ...	1
	11—16.5 ...	10		28—3 ...	4
	11—11.5 ...	15		28—1.5 ...	3
	13—23.5 ...	16		28—1 ...	2
	13—16 ...	15.5		29—4.5 ...	3
	13—20.5 ...	24	Sept.	2—2.2 ...	1
	15—11 ...	5		3—2 ...	1.5
	15—10 ...	10		3—2.5 ...	1.5
	16—12.5 ...	6.5		4—2 ...	2.5
	16—9 ...	9.5		4—2 ...	3.2
	18—8 ...	13.5		6—1.5 ...	0.6
	18—23.5 ...	17.5		6—0.3 ...	0.5
	19—18 ...	18		6—0.7 ...	0.2
	19—15.5 ...	16		6—1.5 ...	1.5
	22—11 ...	9.5		6—1 ...	0.7
	22—9.5 ...	9.5		9—8.5 ...	4
	23—12.5 ...	13		10—1.2 ...	1.5
	23—9 ...	11		11—2 ...	1.7
	23—8.5 ...	6.5		11—1.7 ...	2
	24—20.5 ...	15.5		11—5 ...	3.3
	24—7 ...	15		12—10.5 ...	11
	25—5.5 ...	4.5		13—3.2 ...	4
	25—2.5 ...	3.5		16—7.5 ...	2.5
	25—8 ...	7.5		17—1.5 ...	3
	26—6.5 ...	9		18—12.5 ...	13.5
	26—4 ...	4.5		18—2.5 ...	4.5
	27—6 ...	8		19—2 ...	2.5
	27—3.5 ...	11.5		20—4 ...	6
	27—7 ...	13		20—5 ...	5
				20—2.5 ...	5
				20—2.5 ...	3

Even when the results are very much alike quantitatively they may be very different qualitatively,

## 45.—Along N. shore of Calf Island, April 22nd, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Weight	Shear
Depth in fathoms .....	0	0	10-5	10-5	5	5
Catch in c.cm. ....	9-5	9-5	1-5	1	19-5	52
<i>Biddulphia mobiliensis</i> ...	100	100	50	—	—	—
<i>Chaetoceros contortum</i> ...	—	—	50	50	—	—
<i>Coccinodiscus concinnus</i> ...	100	100	50	85	750	—
<i>Lauderia borealis</i> .....	—	—	20	—	—	—
<i>Ceratium furca</i> .....	—	—	50	25	—	—
„ <i>fuscus</i> .....	100	100	30	—	500	—
„ <i>tripos</i> .....	100	100	—	50	500	—
<i>Peridinium</i> sp. ....	200	200	60	100	500	—
<i>Pleurobrachia pileus</i> .....	—	—	—	—	—	6
Medusoid gonophores .....	50	150	8	4	550	2,600
<i>Sagitta bipunctata</i> .....	—	—	—	1	50	200
<i>Autolytus prolifer</i> .....	—	—	—	—	2	—
<i>Tomopteris onisciformis</i> ...	—	—	—	—	1	2
Larval Polychaeta .....	150	150	5	4	150	900
'Mitraria' .....	50	50	—	—	100	—
Crab zoea .....	4	2	—	—	45	120
Mysis stage of Crangon ...	3	2	—	7	40	800
Nephrops, 1st stage .....	—	—	—	—	8	100
„ 2nd stage .....	—	—	—	—	—	1
<i>Podon intermedium</i> .....	50	50	—	—	100	—
<i>Evadne nordmanni</i> .....	50	100	5	—	200	—
<i>Calanus helgolandicus</i> .....	600	600	15	20	1,000	4,600
<i>Pseudocalanus elongatus</i> .....	400	350	50	20	2,000	300
<i>Temora longicornis</i> .....	500	550	45	50	2,100	950
<i>Centropages hamatus</i> .....	100	50	2	—	—	40
<i>Anomalocera pattersoni</i> ...	—	—	3	—	—	80
<i>Acartia clausi</i> .....	2,200	1,450	55	75	1,400	160
<i>Oithona similis</i> .....	1,100	1,550	15	15	2,000	—
<i>Anomalocera</i> juv. ....	50	50	—	—	50	—
<i>Metridia lucens</i> .....	—	—	—	—	—	25
Copepod nauplii. ....	5,000	5,000	2,500	3,000	6,000	—
„ juv. ....	4,000	3,250	100	100	6,000	—
Barnacle nauplii .....	150	100	5	6	300	600
„ cypris stage ...	24	16	3	3	100	3
<i>Oikopleura</i> sp. ....	750	750	35	25	1,750	280
Fish eggs: Rockling. ....	19	23	—	2	25	100
Whiting .....	3	1	—	—	3	36
Grey Gurnard .....	—	—	—	—	—	10
Red Gurnard .....	—	—	—	—	—	6
Cod .....	—	—	—	—	—	33
Green Cod .....	2	2	—	—	—	31
Haddock .....	—	1	—	—	—	10
Com. Dragonet .....	4	1	—	—	3	15
Spotted Dragonet ...	1	—	—	—	—	2
Bib .....	1	1	—	—	2	30
Brill .....	—	—	—	—	—	2
Topknot .....	—	—	—	—	—	4
Dab .....	1	2	—	—	—	3
Young fishes: Sand-eels ...	—	—	—	—	5	10
Gadoid .....	—	—	—	—	10	40
Pleuronectid .....	—	—	—	—	—	1
Butterfish .....	—	—	—	—	—	3

and it is by no means always the two hauls that are most alike in bulk that agree best in the kind and number of organisms.

On reflection, it will probably be agreed that it is unlikely that, with the large, varied and irregularly scattered population that we find the sea to contain, two nets should often catch the same quantities of the same sets of organisms. Consequently a result like that obtained on April 22nd (Form 45), where the two nets caught precisely the same amounts, and where the lists of organisms constituting the hauls are almost exactly alike both in kinds and numbers, is interesting. It will be noticed how different the catch of the weighted net (exactly similar to B and C but ranging through a lower level of water) was on this occasion. The shear-net being of much larger size and having a much coarser mesh naturally gave very different results. It is not comparable with any of the other nets.

As an example of a case where two similar nets, hauled side by side on the same occasion, gave very nearly the same amount of material, but where the kinds and numbers of organisms present in the catch when examined were found to be very different, I give the following lists of the contents\* of the two surface nets after a 15-minutes haul on April 13th, 1907, at Station III. The one net contained 16 c.c. and the other 15.5 c.c., but these amounts were made up very differently in the two cases. For example, it will be seen that in the net C there were no *Balanus nauplii* and no immature Copepoda, while thousands of both were present in B. Then, again, in B there were very few adult *Temora*, while in C practically all the *Temora* were adult. The lists will show other

\* Only omitting those organisms of which fewer than ten individuals were obtained.



points of difference. We may add that in the haul of the shear-net, taken at the same place and time, there were 1,380 larvae of *Pectinaria* in tubes along with 5,400 *Balanus nauplii*, and many other organisms.

	Net B= 16 c.cm.	Net C= 15.5 c.cm.
Larval Polychaeta .....	650	0
Balanus nauplii.....	3,000	0
„ cypris stage .....	50	0
Copepoda nauplii .....	7,000	2,000
„ juv. ....	13,000	0
Calanus helgolandicus .....	100	6
Pseudocalanus elongatus .....	850	500
Temora longicornis .....	2,470	4,750
Oithona similis .....	100	50
Acartia clausi .....	250	200
Centropages hamatus .....	0	200
Coscinodiscus concinnus .....	8,000	14,000
Biddulphia mobiliensis.....	40,000	70,000
Rhizosolenia semispina .....	1,000	3,000
Lauderia borealis .....	1,000	0
Thalassiosira nordenskioldii ...	2,000	7,000
„ subtilis .....	6,000	0
Chaetoceros teres .....	0	1,000
Peridinium sp. ....	500	0
Plutei .....	500	1,000
Oikopleura sp. ....	2,000	150
Medusoids .....	50	25
Sagitta bipunctata .....	0	48
Crab zoeas .....	0	10

This shows very clearly that the two gatherings, although alike in quantity, were unlike in quality.

Another example (Form 41) is given here from April 19th, where the catch in each case was 18 c.c., but the amount is made up in very different ways. Out of a total of 38 organisms in the two surface nets there are nine which are absent from one or the other net. Of those present in both the numbers differ notably in a few cases, such as 1,000:4,000; 1,000:3,000; and 500:3,000; in other cases again, such as “*Mitraria*” and *Copepod nauplii*, the numbers agree exactly. It will be noticed that the Nansen net caught more than the Hensen—both fishing through the lower half of the water (20 to 10 fathoms)—and that the weighted net, ranging through the upper

## 41.—Off-shore Station I, April 19th, 1907.

Net used .....	I	II	Hensen	Nansen	Weight
Depth in fathoms .....	0	0	20-10	20-10	10-0
Catch in c.cm. ....	18	18	2	8	29
<hr/>					
<i>Biddulphia mobiliensis</i> .....	1,000	4,000	170	700	3,000
<i>Chaetoceros contortum</i> .....	—	1,000	17,000	36,000	—
„ <i>decipiens</i> .....	—	—	500	2,000	—
„ <i>sociale</i> .....	—	—	1,500	1,000	—
<i>Coscinodiscus concinnus</i> .....	1,000	3,000	170	700	500
<i>Ditylium brightwellii</i> .....	—	—	100	500	—
<i>Eucampia zodiacus</i> .....	—	—	—	500	—
<i>Rhizosolenia semispina</i> .....	—	250	100	3,000	—
„ <i>shrubsolei</i> .....	—	—	—	2,000	—
<i>Thalassiosira nordenskioldii</i> ..	—	11,000	40,000	140,000	3,000
<i>Lauderia borealis</i> .....	—	100	8,000	8,000	—
<i>Leptocylindrus danicus</i> .....	—	—	1,000	4,000	—
<i>Ceratium furca</i> .....	—	—	—	700	—
„ <i>fuscus</i> .....	—	—	500	500	—
„ <i>tripos</i> .....	—	—	500	—	1,000
<i>Peridinium</i> sp. ....	500	3,000	1,500	1,000	2,500
Medusoid gonophores .....	150	115	10	125	100
<i>Sagitta bipunctata</i> .....	1	3	5	32	40
Larval <i>Polychaeta</i> .....	110	75	4	8	20
' <i>Mitraria</i> ' .....	350	350	—	—	200
Crab zoea .....	1	—	1	2	10
Mysis stage of <i>Crangon</i> .....	—	—	3	40	104
Nephrops, 1st stage .....	—	—	2	10	34
<i>Podon intermedium</i> .....	—	75	5	—	—
<i>Evadne nordmanni</i> .....	50	330	10	—	50
<i>Calanus helgolandicus</i> .....	600	900	5	125	1,000
<i>Pseudocalanus elongatus</i> ...	700	300	85	1,300	3,800
<i>Temora longicornis</i> .....	700	225	40	550	3,000
<i>Centropages hamatus</i> .....	400	230	5	50	25
<i>Acartia clausi</i> .....	3,000	2,000	45	220	1,250
<i>Oithona similis</i> .....	1,700	2,000	10	25	1,000
<i>Anomalocera</i> juv. ....	100	40	5	—	50
Copepod nauplii. ....	3,000	3,000	10,000	15,000	5,000
„ metanauplii .....	200	190	—	—	50
„ juv. ....	3,000	9,000	75	4,500	8,000
Barnacle nauplii .....	120	80	10	25	50
„ cypris stage .....	12	25	1	1	—
<i>Oikopleura</i> sp. ....	900	650	55	300	650
Fish eggs: Rockling .....	5	2	—	1	—
Whiting .....	9	7	—	—	4
Cod .....	3	8	—	3	4
Green Cod .....	4	3	—	1	7
Bib .....	9	5	—	—	9
Common Dragonet .....	1	3	—	—	1
Haddock .....	1	—	—	—	—
Grey Gurnard .....	—	2	—	—	—
Topknot .....	—	3	—	—	—
Dab .....	4	1	—	—	2
Sprat .....	2	1	—	2	—
Young fishes: Gadoid .....	—	—	—	1	3
Sand-eel .....	—	—	—	—	1

half of the water, caught as usual more than either the deep or the surface nets. We have much evidence of this kind that the most populous zone in the sea is below the surface but above ten fathoms.

We print also Form **42** for comparison with Form **45**. The hauls were taken only three days apart but at different localities, Form **45** representing the along-shore station IV, while Form **42** records a haul from off-shore station II, nearly ten miles off. In **42**, although the amounts in the two surface nets are nearly the same, 15.5 and 16 c.c., still the quantities of the various organisms present differ considerably in the two cases. Of some few (e.g. *Podon* and *Evadne*) the numbers are alike, but with other organisms (*Biddulphia* and *Coscinodiscus*) twice as many are in the one net as in the other; some Copepoda show like numbers, others are in the proportion of nearly ten to one. The Nansen net here, as usual, catches more than the Hensen, and the weighted net with its deeper range more than the otherwise similar surface nets. It will be noticed that the shear-net got relatively large numbers of the larger organisms, *Pleurobrachia*, Medusae, *Sagitta*, and the larger larvae.

Form **42** is of interest also when compared with **41**, representing off-shore station I, at practically the same time (within an hour). They are clearly similar hauls having the same general *facies* although all the numbers differ in detail.

The marked difference of **45** (the later date, April 22nd) to both **41** and **42** (April 19th) in the proportion of Diatoms to Copepoda present is noteworthy. A glance at the lists shows the disproportion, and the total numbers are:—

Form 41:	Diatoms,	300,000;	Copepoda,	22,985
„	42:	„	458,000;	„ 20,218
„	45:	„	1,450;	„ 24,620

## 42.—Off-shore Station II, April 19th, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Weight	Shear
Depth in fathoms .....	0	0	20-10	20-10	10-0	7
Catch in c.cm. ....	15.5	16	3.5	7.5	23.5	28
Biddulphia mobiliensis.....	1,500	3,000	—	700	2,000	—
Chaetoceros contortum ...	—	—	27,000	57,000	2,000	—
„ decipiens .....	—	—	1,000	2,000	—	—
„ sociale .....	—	—	2,000	4,000	—	—
Coscinodiscus concinnus .....	1,500	3,500	300	700	3,500	—
Ditylium brightwellii .....	—	—	500	1,000	—	—
Eucampia zodiacus .....	—	—	500	1,000	—	—
Rhizosolenia semispina ...	500	—	800	3,000	500	—
„ shrubsolei ...	—	—	1,500	—	—	—
Thalassiosira gravida .....	—	—	4,500	1,000	—	—
„ nordenskioldii .....	4,000	5,500	80,000	170,000	45,000	—
Leptocylindrus danicus ...	—	—	4,000	3,000	500	—
Lauderia borealis .....	—	—	10,000	10,000	—	—
Rhizosolenia stouterfothii...	—	—	—	1,000	—	—
Ceratium furca .....	—	1,000	2,500	1,000	500	—
„ fusus .....	—	500	—	—	500	—
„ tripos .....	250	1,500	500	1,000	—	—
Peridinium sp. ....	250	3,000	3,500	6,000	2,000	—
Pleurobrachia pileus .....	—	—	—	—	1	11
Medusoid gonophores ...	150	110	18	60	350	1,100
Sagitta bipunctata .....	2	1	—	3	23	310
Larval Polychaeta .....	5	5	—	5	10	230
Crab zoea .....	—	—	—	1	6	7
Mysis stage of Crangon ...	1	—	5	12	30	145
Nephrops 1st stage .....	—	—	—	2	4	15
Podon intermedium .....	40	40	8	5	20	—
Evadne nordmanni .....	75	75	10	15	250	—
Calanus helgolandicus .....	750	970	30	75	450	300
Pseudocalanus elongatus .....	1,000	187	30	400	2,000	187
Temora longicornis .....	1,100	150	50	150	1,000	670
Centropages hamatus .....	190	112	10	5	50	20
Anomalocera pattersoni ...	80	37	10	—	50	10
Acartia clausi .....	3,000	3,000	75	150	1,700	75
Oithona similis .....	500	500	25	30	1,350	—
Anomalocera juv. ....	260	75	25	—	—	—
Copepod nauplii.....	4,500	8,000	4,000	7,000	10,000	—
„ juv. ....	5,600	6,000	550	1,250	9,500	—
Barnacle nauplii .....	40	40	15	45	100	850
„ cypris stage ...	16	8	2	3	6	—
Oikopleura sp. ....	800	1,200	75	160	1,000	1,250
Fish eggs: Rockling.....	2	—	—	—	—	4
Whiting .....	12	6	—	—	3	6
Cod .....	4	2	—	1	—	—
Grey Gurnard .....	3	4	—	—	1	2
Com. Dragonet .....	3	1	—	—	1	2
Bib .....	14	3	—	1	9	2
Haddock .....	3	1	—	—	1	—
Topknot .....	—	1	—	—	1	2
Dab .....	6	1	—	1	—	—
Sprat .....	2	2	—	—	—	3
Green Cod .....	11	1	—	—	—	1
Young fishes: Plaice .....	—	—	—	1	—	—
Gadoid .....	—	—	—	—	6	6



The Copepoda are remaining fairly constant, while the Diatoms, having passed their spring maximum, are falling off rapidly.

On Forms **16**, **19**, we give the results of hauls taken on the along-shore station III, off the Slock, on two adjoining days, April 9th and 10th. The two surface hauls are very unlike in quantity, although practically the same series of organisms is represented. Such numbers as 37,000 to 1,500; 4,000 to 250; and 19,000 to 550 indicate a considerable disproportion. The surface plankton, then, if we may judge from these two samples, had fallen on April 10th to less than half what it had been on the previous day. But if we compare the two hauls taken on April 10th, we find that the second net towed simultaneously with the first, but at about a fathom below the surface, yielded a much more abundant gathering. On looking into the details one finds that all the Diatoms and *Ceratium tripos* are more numerous in the deeper haul, while the larger organisms—Medusae, Larvae, Copepoda, and Oikopleura—are more abundant on the surface. Some of the Diatoms showed a great increase below the surface, the extreme case being *Chaetoceros contortum* with 120,000 at one fathom to 1,500 at the surface.

On the other hand during the later summer we met with cases where the Copepoda and other larger organisms were much more abundant in a zone below the surface. Here is an example (Form **84**) from off-shore station II, on August 27, where the weighted net brought up 7·5 c.c. as against 1 c.c. in each of the surface nets—all three nets being alike and used simultaneously. The relatively large numbers of *Acartia*, *Pseudocalanus*, and Copepod Nauplii will be noticed. The two surface nets on this occasion yielded identical quantities, but the detailed

## 16, 19.—Three miles off Stock.

	(16) April 9th	(19) April 10th	
Depth in fathoms .....	0	0	1
Catch in c.cm. ....	33	13	20
<i>Biddulphia mobiliensis</i> .....	11,000	8,000	12,000
<i>Chaetoceros contortum</i> .....	37,000	1,500	120,000
„ <i>decipiens</i> .....	4,000	250	8,000
„ <i>teres</i> .....	—	—	500
<i>Coscinodiscus concinnus</i> .....	7,000	3,500	5,000
<i>Rhizosolenia semispina</i> .....	—	150	300
<i>Thalassiosira nordenskiöldii</i> ...	21,000	1,500	78,000
„ <i>subtilis</i> .....	—	500	3,000
<i>Lauderia borealis</i> .....	—	—	5,000
<i>Ceratium fusus</i> .....	—	—	200
„ <i>tripos</i> .....	1,000	100	1,000
<i>Peridinium</i> sp. ....	1,000	100	—
Medusoid gonophores .....	—	75	90
<i>Sagitta bipunctata</i> .....	11	—	—
„ <i>Mitraria</i> .....	—	250	100
Crab zoea .....	30	—	—
Mysis stage of Crangon .....	2	—	—
Larval Nephrops, 1st stage ...	4	—	—
<i>Podon intermedium</i> .....	—	20	—
<i>Evadne nordmanni</i> .....	500	—	—
<i>Calanus helgolandicus</i> .....	50	100	60
<i>Pseudocalanus elongatus</i> .....	16,000	2,200	1,000
<i>Temora longicornis</i> .....	19,000	550	220
<i>Centropages hamatus</i> .....	600	30	15
<i>Acartia clausi</i> .....	1,000	185	75
<i>Oithona similis</i> .....	—	90	75
<i>Anomalocera</i> juv. ....	200	20	15
Copepod nauplii .....	8,000	5,000	4,000
„ juv. ....	6,000	2,250	900
Barnacle nauplii .....	—	825	550
„ cypris stage .....	6	10	8
<i>Oikopleura</i> sp. ....	100	2,000	1,000
Fish eggs—			
Rockling .....	2	2	3
Grey Gurnard .....	12	—	—
Common Dragonet .....	13	3	3
Spotted Dragonet.....	—	1	—
Bib .....	26	2	2
Red Gurnard.....	—	1	—
Whiting .....	132	4	3
Sail Fluke .....	—	1	—
Dab .....	14	2	—
Long Rough Dab .....	1	—	—
Cod .....	55	1	—
Green Cod .....	26	—	—
Topknot .....	—	—	1
Haddock .....	22	—	—
Plaice .....	1	—	—
Sprat .....	23	—	—

figures for the species are in nearly every case different, although, as we have pointed out in other examples, they are of the same "order."

**84.**—Train Bank, August 27th.

Depth in fathoms .....	0	0	Weight
Catch in c.cm. ....	1	1	7½
Chaetoceros teres .....	30	50	—
Coscinodiscus concinnus .....	40	75	—
Coscinodiscus radiatus .....	—	—	200
Ceratium fusus .....	50	250	—
„ tripos.....	150	600	400
Trochiscia sp.....	40	100	100
Sagitta bipunctata .....	3	1	27
Crab zoea .....	—	—	4
Mysis stage of Crangon .....	—	—	2
Calanus helgolandicus .....	5	4	1 200
Pseudocalanus elongatus .....	80	70	3,000
Temora longicornis .....	10	20	500
Centropages hamatus .....	30	10	100
Anomalocera pattersoni .....	4	—	—
Acartia clausi .....	550	500	24,700
Oithona similis .....	15	—	—
Isias clavipes .....	30	30	—
Parapontella brevicornis.....	—	3	—
Paracalanus parvus .....	20	15	—
Copepod nauplii.....	9,000	7,000	26,500
„ juv.....	2,000	1,500	7,000
Gasteropods, larval .....	50	150	200
Fish eggs—Rockling.....	—	1	1
Ascidian eggs .....	2,500	1,000	2,400

COMPARISON OF DEEP AND SURFACE HAULS.

We have shown in the previous section that in some cases (April) the surface gatherings contain more Copepoda and larval forms, and in others (August) these larger organisms are more abundant in deeper zones (see Forms **19** and **84**). When a comparison is made between the three similar open tow-nets which were worked together for 15 minutes at a time—two, at or close to, the surface (0 fathoms) and the other weighted so that it was lowered to a depth of about ten fathoms, and gradually rose, as the boat went slowly ahead, to a depth of a

fathom or two below the surface—it is almost invariably found that the weighted net, with its wider range through the deeper layers of waters, gave a larger, and sometimes a much larger, quantity of organisms. The only exceptions to this rule are on some occasions in April, when the sea was full of Diatoms and the surface nets gave very large hauls, equal to or even exceeding the deeper ones. But even during the Diatom maximum in April some days showed more in the weighted than in the surface nets. For example, on April 10th, at along-shore station III (Form **22**), the surface gave 11·5 and the net at one fathom 19·5 c.c., and the total Diatoms were 27,000 in the former and 188,000 in the latter (see also Form **19**, same date, above).

Such numbers as 18, 18, 29; 3, 3, 6·5; 15·5, 16, 23·5; 9·5, 9·5, 19·5; and 9, 11, 18 are frequent. On April 25th, the numbers are 5·5, 4·5 at the surface and 20 in the deeper net. In some cases the difference is even more marked, as, for example, on August 24th, at off-shore station II, when the surface nets gave respectively 2 and 1·5 c.c., while the weighted net gave 16 c.c. The increase in this case was due to Copepoda being more abundant in the lower zone, especially *Acartia clausi* (23,000), *Oithona similis* (1,500), and Copepod nauplii (70,000). Other similar results were obtained at the same locality on neighbouring days.

Here is a haul (Form **38**) ten miles off shore, in April, where the two surface nets gave very different results and the weighted net did not exceed them in quantity. The bulk of the catch in all three nets was Copepoda both young and old. *Oikopleura* is rather evenly distributed in these nets, there being roughly 3,000 in each. The shear-net haul was taken on the way in, half-way between the Calf Island and Port Erin, and shows an extraordinary



**38.**—Off-shore Station II, April 18th, 1907.

Net used .....	Surface	Surface	Hensen	Nansen	Weight	Shear
Depth in fathoms .....	0	0	20-10	20-10	10-0	7
Catch in c.cm. ....	23·5	17·5	5·5	9·5	17·5	27·5
<i>Biddulphia mobiliensis</i> .....	750	2,250	500	250	2,500	1,000
<i>Chaetoceros contortum</i> ...	—	250	36,000	63,000	500	250
„ <i>debile</i> .....	—	—	—	2,000	—	—
„ <i>decipiens</i> .....	—	—	2,500	4,000	—	—
„ <i>sociale</i> .....	—	—	1,500	2,000	—	—
<i>Coscinodiscus concinnus</i> ...	1,750	2,750	200	250	1,100	200
<i>Ditylium brightwellii</i> .....	—	—	500	—	—	—
<i>Eucampia zodiacus</i> .....	—	—	1,000	—	—	—
<i>Lauderia borealis</i> .....	—	—	5,000	14,000	500	—
<i>Rhizosolenia shrubsolei</i> ...	250	250	2,000	2,000	500	—
„ <i>stolterfothii</i> ...	—	—	1,000	2,000	—	—
<i>Thalassiosira gravida</i> .....	—	—	500	1,000	—	—
„ <i>nordenskioldii</i> .....	2,000	4,500	65,000	134,000	8,500	500
<i>Leptocylindrus danicus</i> ...	—	—	4,000	3,000	250	—
<i>Ceratium furca</i> .....	—	—	1,000	500	—	—
„ <i>fuscus</i> .....	250	250	—	500	1,500	—
„ <i>tripos</i> .....	500	750	—	—	1,000	—
<i>Peridinium</i> sp. ....	—	2,250	500	6,000	750	—
<i>Acanthometra</i> sp. ....	—	—	—	100	50	—
Medusoid gonophores .....	200	250	10	120	300	1,800
Plutei of Echinoderms ...	200	200	—	—	—	—
<i>Sagitta bipunctata</i> .....	12	—	1	6	27	123
<i>Autolytus prolifer</i> .....	—	—	—	—	—	1
Larval Polychaeta .....	60	50	—	20	20	250
'Mitraria' .....	400	250	—	—	500	—
Crab zoea .....	20	—	—	—	8	16
Mysis stage of Crangon ...	2	—	2	10	37	72
Nephrops first stage.....	—	—	—	4	4	11
Podon intermedium .....	150	150	—	—	—	—
<i>Evadne nordmanni</i> .....	100	100	—	—	150	50
<i>Calanus helgolandicus</i> .....	1,600	600	10	120	1,200	850
<i>Pseudocalanus elongatus</i> .....	200	150	100	770	1,600	500
<i>Temora longicornis</i> .....	300	200	30	150	2,300	750
<i>Centropages hamatus</i> .....	100	100	—	—	—	50
<i>Anomalocera pattersoni</i> ...	500	400	5	—	—	—
<i>Acartia clausi</i> .....	2,600	2,400	40	125	1,600	50
<i>Oithona similis</i> .....	400	300	5	50	150	—
Copepod nauplii.....	250	4,500	4,000	—	7,000	250
„ juv. ....	2,000	3,000	100	18,000	4,000	150
Barnacle nauplii .....	30	25	10	75	75	650
„ cypris stage .....	2	—	1	—	—	6
<i>Oikopleura</i> sp. ....	3,300	2,750	140	500	3,300	750
Fish eggs:—Rockling ...	6	1	—	—	—	9
Common Dragonet ...	10	2	—	—	4	7
Topknot .....	1	3	—	—	—	—
Bib .....	9	8	1	1	2	5
Whiting .....	13	12	—	—	11	3
Cod .....	8	1	—	—	—	1
Green Cod .....	1	3	—	2	2	4
Haddock .....	1	4	—	—	—	—
Gurnard .....	—	1	—	—	2	—
Dab .....	—	5	—	—	—	—
Sprat .....	—	1	—	—	—	2
Spotted Dragonet.....	—	—	—	—	—	1
Young fishes: Gadoid .....	—	—	1	1	2	10
Clupeoids .....	—	—	—	—	—	10

number of Medusoids, most of which were *Hybocodon prolifer*.

Form **87** shows a set of hauls at the end of August on Station V inside the Wart Bank. One remarkable

**87.**—Station V, August 29th.

Net used .....	Surface	Surface	Hensen	Nansen	Weight
Depth in fathoms .....	0	0	14.7	14.7	10.0
Catch in c.cm. ....	4.5	3	.3	.7	30
<i>Biddulphia mobiliensis</i> .....	700	750	20	50	1,000
<i>Chaetoceros contortum</i> .....	—	—	15	10	—
„ <i>decipiens</i> .....	—	—	15	—	—
<i>Coscinodiscus radiatus</i> .....	—	—	10	—	—
„ <i>concinus</i> .....	—	200	—	—	—
<i>Rhizosolenia semispina</i> .....	250	1,000	25	10	—
<i>Ceratium fusus</i> .....	—	500	10	10	500
„ <i>tripos</i> .....	250	2,750	70	20	1,000
<i>Peridinium</i> sp.....	250	300	5	—	—
<i>Trochiscia brachiolata</i> .....	—	200	10	25	250
<i>Sagitta bipunctata</i> .....	27	21	—	1	125
<i>Tomopteris onisciformis</i> .....	—	1	—	—	—
Larval Polychaeta .....	200	—	40	—	—
'Mitraria' .....	75	—	—	—	—
Crab zoea .....	—	—	—	—	2
„ megalopa .....	1	—	—	—	—
Mysis stage of Crangon .....	5	3	—	3	36
Podon intermedium .....	10	—	—	—	15
<i>Calanus helgolandicus</i> .....	34	7	—	—	67
<i>Pseudocalanus elongatus</i> .....	4,500	830	100	325	23,000
<i>Temora longicornis</i> .....	200	25	8	10	700
<i>Centropages hamatus</i> .....	150	25	5	10	200
<i>Acartia clausi</i> .....	1,255	150	8	100	6,000
<i>Oithona similis</i> .....	4,500	3,250	35	15	6,500
<i>Paracalanus parvus</i> .....	200	150	4	6	—
<i>Isias clavipes</i> .....	—	25	—	—	300
<i>Leptosyllus</i> sp. ....	—	—	150	—	—
<i>Ameira intermedia</i> .....	—	—	4	—	—
<i>Zaus goodsiri</i> .....	—	—	—	—	2
Copepod nauplii .....	17,000	22,500	340	2,450	38,000
„ juv. ....	15,000	750	40	600	19,000
Gasteropods, larval .....	250	200	20	50	500
Lamellibranchs, larval .....	250	500	20	50	500
<i>Oikopleura</i> sp. ....	875	900	25	10	—
Ascidian eggs .....	1,500	1,500	—	—	2,000
Young fishes .....	—	—	—	—	6

feature of this occasion was that the Hensen net, hauled up from 14 fathoms, contained 150 specimens of what is probably a new species of *Leptosyllus*, while the Nansen

net used at the same time, and at the same depth, on the other side of the ship, caught twice as much material but not a single specimen of the new Copepod. The surface nets are also somewhat divergent in their results, while the deeper weighted net has caught a very much larger quantity of material, the greater part of which is clearly made up of Copepoda both young and old—about ninety-five thousand in all.

#### RESULTS OF THE VERTICAL HAULS.

The two vertical closing nets we have used from the "Ladybird" are the Petersen-Hensen and the Nansen, both of which have now been thoroughly tested, and have given on the whole good results. The ring of the Petersen-Hensen net is 19 inches in diameter, and the opening at the mouth into which the brass lids fit is  $7\frac{1}{5}$  inches. The opening of the Nansen net (figs. 3 and 4) is 14 inches.

As a vertical closing net we prefer the Nansen to the Petersen-Hensen. It is lighter and less complicated (a matter of some importance in a rough sea), more easily manipulated, less liable to failure in action, costs less and generally catches more. The brass cylinder at the lower end is, however, too small, and might be improved in other ways.

These two vertical closing tow-nets are obviously not comparable one with the other. Their dimensions are different, and the results of the hauls are usually also very different, the Nansen net almost invariably catching more than the Hensen. The maximum amount for the Hensen is 64·5, while the maximum for the Nansen is more than twice as much, namely, 164 c.c. These two nets were not used for the purpose of obtaining results that would be comparable, but were used for the purpose of testing the

nets to see which was the more efficient and convenient, and also for the purpose of obtaining corroborative evidence as to the distribution of organisms by means of a second and different net used at the same time. Consequently, the results obtained from the two nets cannot be summed, but must be treated separately. The usual plan of working at the off-shore stations was that, after



FIG. 3.—Nansen net going down open.

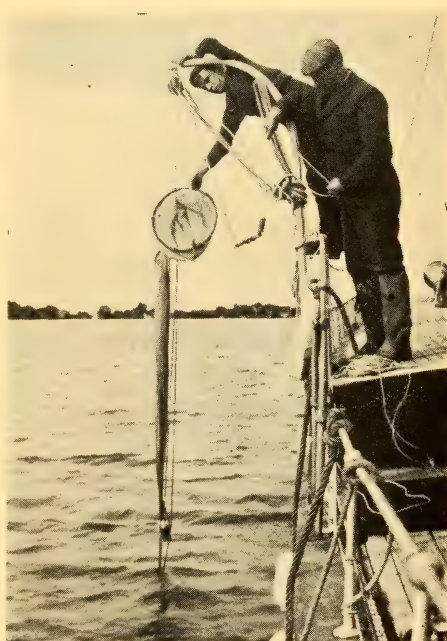


FIG. 4.—Nansen net coming up closed.

ascertaining the depth, these vertical nets were lowered simultaneously to within a fathom or so of the bottom and were hauled up through the lower ten fathoms of water and then closed by means of the messengers. Thus, the Hensen and Nansen nets brought us up samples of the fauna in the bottom ten fathoms, for comparison with the



fauna of the upper zones of the sea obtained by means of the surface and weighted open tow-nets.

In many of these hauls during April (see Form **10**, p. 211) the vertical nets, although they had traversed a very much smaller area of water, brought up a very much larger number of Diatoms, for example in the case of *Chaetoceros contortum*—14,000,000 in the Nansen and 286,000 in the Hensen, as against 160,000 in the weight net and smaller numbers in those at the surface. Other cases may not be so striking as this one, but still it is true of many hauls that the Nansen net, especially, brought a large number of Diatoms from the lower zone of water.

In cases where, as on Form **71**, p. 201, the Hensen and Nansen nets have yielded smaller numbers, say, of Copepoda than the weighted and surface nets no conclusions can be drawn, as it must always be remembered that the open tow-nets have sampled very much larger volumes of water than have passed through the vertical nets. Form **21**, p. 209, shows a case where the Nansen net, as usual, has caught much more than the Hensen, but where it has not caught more than the average of the three open tow-nets in the water above, but still when the constitution of the catch is analysed it is noted that most of the Diatoms are in the Nansen and Hensen nets, and that the greater bulk of the catches from the upper layers of water is made up of Copepoda and other larger organisms.

It is rare for the Hensen net to catch more than the Nansen, but an example of that is seen on Form **45**, p. 218. The slight difference in bulk (0·5 c.c.) is, however, probably due in this case to the presence of a few Copepoda, Medusae and Oikopleura, and is thus of an accidental or non-significant nature. Form **41** on p. 221 shows what we consider to be a fairly representative series

of catches on an off-shore station, the Nansen being greater than the Hensen and the three open nets being greater still, while the weight net has caught more again than those on the surface. Form 42 on the second off-shore station at the same date shows a very similar proportion between the catches. Many other similar examples might be given. On the other hand, there are cases, such as station III on April 4th, when the Hensen and Nansen brought up such enormous quantities of Diatoms from the lower zone of water as to outnumber many times over the catch of all the other nets put together. On this occasion, the Hensen nets caught 64.5 c.c. and the Nansen 164 c.c., and several numbers of individual species of Diatoms in a single net run into millions, *Chaetoceros contortum* being estimated at fifteen millions in the Nansen net. On the following day at the second off-shore station the number of that Diatom is estimated at fourteen millions and the total amount in the Nansen net was 100 c.c., while the Hensen had only 12.5 c.c. The surface nets were 9 and 12 respectively, and the weighted net 15.5 c.c.

Although the numbers are not so high in the case of other groups, the same general principle holds later in April, when the Diatoms are disappearing and the Copepods are more abundant. We find that the Nansen net still obtains a much larger catch, and that the bulk of it is then made up of adult and larval Copepoda. For example, on April 22nd, at off-shore station I, the Nansen catch was 6 c.c. and the Hensen 1 c.c. The Nansen had 2,250 Copepoda and the Hensen 185; the Nansen had 15,000 Copepod Nauplii, and the Hensen 3,000; the Nansen had 1,500 later Copepod larvae, and the Hensen had 250; the Nansen had 1,000 Oikopleura, and the Hensen 125. Many other similar examples might be given.

One of our objects throughout this work was to sample the various layers of water, as well as to compare neighbouring localities and adjoining dates, and the following diagrammatic statement of certain of the hauls taken on September 12th will illustrate that part of the plan of the work:—

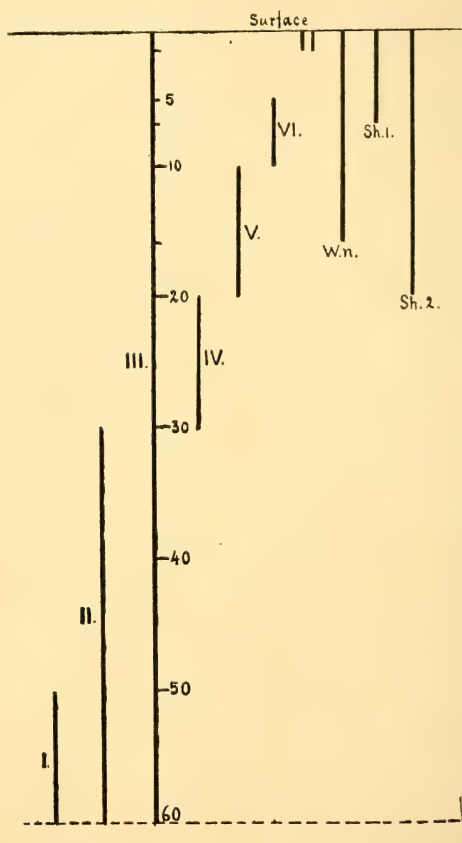


FIG. 5.—Diagram to show the hauls taken at one station. I.—VI. represent hauls of the vertical closing nets; W.n. (weight net), Sh. 1 and Sh. 2 (shear net) and the two surface nets represent horizontal or oblique hauls. The numbers 5 to 60 indicate depths in fathoms.

Here, out in the middle of the channel between Ireland and the Isle of Man, the depth was about 65 fathoms, and we sank our vertical nets down to 60, and hauled them up through the lower ten fathoms (I), the lower thirty (II), and the entire depth (III), then through the zones 30 to 20 (IV), twenty to ten (V), and ten to five (VI). That brought us in touch with the surface zone through which the weight-net, the shear-nets and the surface-nets had ranged. In this way we hoped to be able to localise the constituents of the fauna obtained in a vertical haul such as III.

It is clear that much further work in this direction is needed. Some of these serial hauls support the idea that there is a definite zone beneath the surface holding the maximum of organisms; but other hauls again seem to give contradictory evidence. For example, in the Hensen net hauls represented in the diagram (fig. 5) dealing with September 12th, Hensen I and Hensen II and Hensen IV all contained very small quantities of material, 0.1 c.c., each, while Hensen VI contained a very little more, 0.15 c.c. Hensen III, open all the way from the bottom to the surface, contained distinctly more material, 0.25 c.c., and Hensen VI drawn through a narrow zone of five fathoms only (ten to five fathoms) contained as much as Hensen III, indicating that most of the organisms were on this occasion contained in this narrow zone between five and ten fathoms. The Nansen hauls, on the other hand, did not bear this out, No. II and No. V containing more than either III or VI.

We feel that we have not yet sufficient data as to these serial vertical hauls to make it possible to discuss the matter of zonal distribution further at present.



## DISCUSSION OF THE GROUPS.

Turning now to the details of the various groups of organisms in the different hauls throughout the year we have, first of all, taken out the numbers of these groups from the lists day by day, dividing the totals by the number of hauls of the nets made on that day, so as to get results for each group, per day, per net. We have treated in that way the Diatoms, the Dinoflagellates, the Copepoda, the Cladocera, and a few of the more prominent single species such as *Ceratium tripos*, *Sagitta bipunctata*, *Tomopteris onisciformis*, *Oikopleura dioica*, and some of the Copepoda.

## DIATOMS.

The variation in the total catch of Diatoms throughout the year will be seen from the following list. All the days upon which plankton gatherings were taken are recorded, and the Diatoms from all nets on each day are added together, the average per net for that day being given in the last column.

		Nets.	Total.		Average per net.
Jan.	8	... 1 =	5,650	...	5,650
	18	... 1 =	34,300	...	34,300
Feb.	5	... 1 =	152,600	...	152,600
	22	... 1 =	205,050	...	205,050
	26	... 4 =	293,900	...	73,475
Mar.	4	... 3 =	284,000	...	94,666
	26	... 2 =	220,000	...	110,000
	27	... 1 =	277,000	...	277,000
	29	... 1 =	326,000	}	101,330
	29	... 4 =	180,650		
Apr.	1	... 5 =	425,000	}	118,500
	1	... 3 =	523,000		
	2	... 4 =	1,000,000	...	250,000
	3	... 1 =	335,000	...	335,000
	4	... 4 =	890,000	}	2,369,333
	4	... 5 =	20,434,000		
	5	... 5 =	17,669,000	...	3,533,800
	6	... 2 =	697,500	...	348,750
	8	... 5 =	12,362,000	}	1,720,600
	8	... 5 =	4,844,000		
	9	... 5 =	1,249,000	}	200,429
	9	... 5 =	696,000		
	9	... 2 =	159,000	}	
	9	... 2 =	702,000		

## SEA-FISHERIES LABORATORY.

		Nets.	Total.		Average per net.
Apr.	10	2 =	247,000	}	297,706
	10	5 =	3,662,000		
	10	5 =	324,000		
	10	3 =	414,000		
	10	2 =	414,000		
	11	5 =	2,533,000	}	380,875
	11	3 =	514,000		
	13	5 =	2,269,000	}	204,867
	13	3 =	162,000		
	13	5 =	410,000		
	13	2 =	232,000		
	15	5 =	319,000		
	15	5 =	528,000	}	93,727
	15	1 =	184,000		
	16	5 =	352,000	}	44,600
	16	6 =	107,000		
	16	3 =	88,000		
	16	1 =	122,000		
	17	1 =	215,000		
	18	6 =	371,000	}	59,286
	18	5 =	377,000		
	18	2 =	9,000		
	18	1 =	73,000		
	19	5 =	300,000		
	19	5 =	458,000	}	74,455
	19	1 =	61,000		
	22	5 =	1,700	}	600
	22	5 =	1,400		
	22	1 =	3,500		
	23	3 =	1,500	}	1,342
	23	5 =	4,300		
	23	3 =	1,300		
	23	1 =	9,000		
	24	4 =	2,663,000		
	24	5 =	1,452	}	191,873
	24	5 =	211,000		
	24	1 =	2,650		
	25	5 =	6,200		
	25	5 =	900		
	25	4 =	1,500	}	663
	25	1 =	1,350		
	26	6 =	200,000	}	16,982
	26	5 =	3,530		
	26	1 =	250		
	27	5 =	64,000		
	27	6 =	51,000		
	27	5 =	202,000	}	16,890
	27	5 =	6,770		
	27	1 =	47,800		
May	8	1 =	238,650	...	238,650
	18	1 =	15,250	...	15,250
	24	1 =	39,650	...	39,650
June	11	1 =	103,000	...	103,000
	15	1 =	8,500	...	8,500
	27	1 =	6,075	...	6,075
July	5	1 =	61,475	...	61,475
	12	1 =	47,450	...	47,450
	17	1 =	44,450	...	44,450
	31	1 =	50	...	50
Aug.	9 to 20.	—No Diatoms.			
	21	6 =	25	}	6
	21	5 =	40		

TRANSACTIONS LIVERPOOL BIOLOGICAL SOCIETY.

			Nets.	Total.		Average per net.
Aug.	23	...	3 =	4		
	23	...	4 =	60	...	8
	23	...	5 =	30		
	24	...	3 =	70		
	24	...	5 =	340		
	24	...	4 =	6,060	...	425
	24	...	7 =	1,600		
	26	...	6 =	580		
	26	...	6 =	105	...	57
	27	...	3 =	400	...	133
	28	...	6 =	3,270		
	28	...	8 =	1,480	...	339
	29	...	5 =	4,055	...	811
	30	...	1 =	250	...	250
	31	...	12 =	2,610	...	217
Sept.	2	...	6 =	460	...	76
	3	...	3 =	2,475		
	3	...	8 =	5,485	...	724
	4	...	9 =	3,000		
	4	...	5 =	4,528	...	575
	4	...	5 =	3,400		
	6	...	9 =	2,600		
	6	...	9 =	6,484	...	390
	6	...	9 =	1,445		
	9	...	3 =	28,400	...	9,467
	10	...	7 =	6,340	...	906
	11	...	8 =	3,900		
	11	...	8 =	4,925	...	743
	11	...	8 =	9,000		
	12	...	8 =	29,960,000		
	12	...	8 =	70,000	...	1,843,684
	12	...	3 =	5,000,000		
	13	...	3 =	2,980	...	993
	14	...	1 =	1,600	...	1,600
	16	...	7 =	5,658	...	808
	17	...	7 =	55,000		
	17	...	7 =	25,000	...	5,714
	18	...	7 =	2,777		
	18	...	8 =	16,000	...	1,252
	19	...	8 =	12,317	...	1,539
	20	...	9 =	4,245,000		
	20	...	9 =	88,000		
	20	...	9 =	558,000	...	477,664
	20	...	5 =	10,394,250		
	21	...	1 =	8,000	...	8,000
	23	...	1 =	11,550	...	11,550
	24	...	1 =	31,950	...	31,950
	26	...	1 =	103,655	...	103,655
	27	...	1 =	128,350	...	128,350
	28	...	1 =	156,150	...	156,150
	30	...	1 =	579,250	...	579,250
Oct.	1	...	1 =	91,050	...	91,050
	9	...	1 =	2,450	...	2,450
	14	...	1 =	0	...	0
	24	...	1 =	3,500	...	3,500
Nov.	4	...	1 =	6,530	...	6,530
	8	...	1 =	159,300	...	159,300
	16	...	1 =	26,685	...	26,685
	25	...	1 =	75,075	...	75,075
Dec.	12	...	1 =	13,820	...	13,820
	20	...	1 =	11,450	...	11,450
	23	...	1 =	6,950	...	6,950
	30	...	1 =	8,000	...	8,000

From these daily averages a three-days' average has now been made, with results as follows :—

Nets	Daily Average	3-daily Average	Nets	Daily Average	3-daily Average
2. Mar. 26—	110,000	—	12. Aug. 26—	57	205
1. 27—	277,000	162,777	3. 27—	133	176
5. 29—	101,330	165,610	14. 28—	339	428
8. April 1—	118,500	156,610	5. 29—	811	467
4. 2—	250,000	234,500	1. 30—	250	426
1. 3—	335,000	738,583	12. 31—	217	181
9. 4—	2,369,333	2,079,378	6. Sept. 2—	76	339
5. 5—	3,533,800	2,083,961	11. 3—	724	458
2. 6—	348,750	1,867,717	19. 4—	575	563
10. 8—	1,720,600	756,593	27. 6—	390	3,477
14. 9—	200,429	739,578	3. 9—	9,467	3,588
17. 10—	297,706	326,345	7. 10—	906	3,705
8. 11—	380,900	294,491	24. 11—	743	615,111
15. 13—	204,867	226,498	19. 12—	1,843,684	615,140
11. 15—	93,727	114,398	3. 13—	993	615,426
15. 16—	44,600	114,442	1. 14—	1,600	1,134
1. 17—	215,000	106,295	7. 16—	808	2,707
14. 18—	59,286	116,247	14. 17—	5,714	2,591
11. 19—	74,455	44,780	15. 18—	1,252	2,835
11. 22—	600	25,466	8. 19—	1,539	160,152
12. 23—	1,342	64,605	32. 20—	477,664	162,401
15. 24—	191,873	64,626	1. 21—	8,000	165,738
15. 25—	663	69,839	1. 23—	11,550	17,167
12. 26—	16,982	11,512	1. 24—	31,950	49,052
22. 27—	16,890	—	1. 26—	103,655	88,652
Aug. 20—	—	2	1. 27—	130,350	120,785
11. 21—	6	2	1. 28—	128,350	279,317
22—	—	5	1. 30—	579,250	266,217
12. 23—	8	144	1. Oct. 1—	91,050	—
19. 24—	425	163			

On considering this list, the following points come out:—The average number of Diatoms per catch often varies considerably from day to day, as will be seen by a glance at the table. Thus on April 5th the average of all catches of that day was 3,533,800, while on April 6th it fell to 348,750; on April 24th it was 191,873, while on April 25th it was only 663. Again, on September 10th and 11th it was 906 and 743 respectively, but rose to 1,843,684 on the following day; on September 19th it was 1,539, while on September 20th it was 477,664.

Each of the above numbers, however, is the average of several catches, that is of all the nettings taken during



a single day, and they do not by any means give an adequate idea of the quantitative variation among individual catches. Thus on September 10th surface nets I and II contained 250 and 550 respectively, while two days later the corresponding numbers were 13,495,500 and 16,300,500; on April 8th two hauls of the Nansen net gave respectively 198,000 and 3,739,000, and many other such cases could be quoted.

Such differences as above cited are due in the main to the great abundance of some single organism, generally *Rhizosolenia semispina*, *Chaetoceros contortum*, *C. debile* or *Thalassiosira nordenskioldii*. Thus of the two enormous surface nettings of September 12th given above, *Rhizosolenia semispina* accounts for thirteen millions and sixteen millions of the organisms respectively; again the high average (477,664) of 32 hauls made on September 20th is traceable largely to the influence of four of the catches amounting together to 13,230,150, of which 13,085,000 were *Rhizosolenia semispina*.

Besides, however, these great fluctuating changes it will be seen that there is a more regular seasonal change. This is brought out more clearly by the diagram (p. 269). Owing to the frequency of the spring and autumn hauls it is possible to take 3-daily averages from March 27th to April 26th, and again from August 20th to September 30th, but it should be noted that while the spring catches and those of the middle (August 23rd to September 19th) of the autumn period were made with several kinds of nets outside the Bay, together with surface nets within the Bay, those on other occasions were made only by the surface nets within the Bay; at other times than the above two periods the nettings numbered from three to four per month.

The curve shows two humps, a well-marked one in

early April and a less conspicuous one during the latter half of September.

The spring hump rises suddenly and falls again almost as suddenly, the main portion occupying about three weeks (the last week in March and the first fortnight in April). It is to be noted that its height is largely influenced by the catches of three days, namely, April 4th (2,369,333), April 5th (3,533,800) and April 8th (1,720,600), which were due mainly to the large numbers of *Chaetoceros contortum*, *C. debile* and *Thalassiosira nordenskioldii* in certain of the nettings included. Omitting these three days, however, the curve retains the same general character as before, except that the peak is very materially reduced.

The autumn hump is not so well marked, in fact if the catches of the three days, September 12th, 20th and 30th, be omitted it almost entirely disappears and is confined to the last week in September; it depends, moreover, entirely upon surface nettings taken in the Bay.

At other times of the year the catches were small, reaching, however, about 200,000 now and then sporadically. The minima were during August, October and December, in particular from August 9th to August 20th, when no Diatoms were taken, though surface nettings were made (within the Bay) on all the days with two exceptions.

#### DINOFLAGELLATA.

The following list of the Dinoflagellata throughout the year is drawn up on exactly the same lines as that for the Diatoms.

			Nets.	Total.	Average per Net.
Jan.	8	...	1 =	0	...
	18	...	1 =	100	...
Feb.	5	...	1 =	1,400	...
					1,400

			Nets.	Total.	Average per Net.
Feb.	22	...	1 =	750	750
	26	...	4 =	300	75
Mar.	4	...	3 =	0	0
	26	...	2 =	4,000	2,000
	29	...	5 =	7,900	1,580
April	1	...	8 =	14,900	1,862
	2	...	4 =	3,500	875
	4	...	9 =	5,700	633
	5	...	5 =	16,500	3,300
	6	...	2 =	3,600	1,800
	8	...	10 =	30,050	3,005
	9	...	14 =	79,850	5,704
	10	...	17 =	84,350	4,962
	11	...	8 =	12,500	1,562
	13	...	15 =	29,350	1,957
	15	...	11 =	36,450	3,313
	16	...	15 =	31,245	2,083
	17	...	1 =	4,500	4,500
	18	...	14 =	38,125	2,723
	19	...	11 =	43,700	3,972
	22	...	11 =	7,895	717
	23	...	12 =	11,100	925
	24	...	15 =	49,259	3,284
	25	...	15 =	14,248	950
	26	...	14 =	39,735	2,838
	27	...	18 =	32,255	1,792
May	8	...	1 =	3,575	3,575
	18	...	1 =	1,850	1,850
	24	...	1 =	3,000	3,000
June	11	...	1 =	5,000	5,000
	15	...	1 =	375	375
	27	...	1 =	3,000	3,000
July	5	...	1 =	2,575	2,575
	12	...	1 =	3,375	3,375
	17	...	1 =	8,000	8,000
	31	...	1 =	3,750	3,750
Aug.	9	...	1 =	0	0
	10	...	1 =	1,000	1,000
	12	...	1 =	2,000	2,000
	13	...	1 =	2,000	2,000
	14	...	1 =	1,000	1,000
	15	...	1 =	1,000	1,000
	16	...	1 =	500	500
	17	...	4 =	112	28
	19	...	4 =	787	197
	20	...	5 =	1,582	316
	21	...	13 =	8,201	631
	22	...	1 =	875	875
	23	...	15 =	3,244	216
	24	...	19 =	5,250	276
	26	...	12 =	1,190	99
	27	...	3 =	1,735	578
	28	...	14 =	9,095	650
	29	...	5 =	5,665	1,133
	30	...	1 =	300	300
	31	...	12 =	3,605	300

		Nets.	Total.		Average per net.
Sept.	2	... 6 =	2,235	...	372
	3	... 11 =	16,611	...	1,510
	4	... 19 =	6,305	...	332
	5	... 1 =	50	...	50
	6	... 26 =	11,356	...	436
	9	... 3 =	10,900	...	3,633
	10	... 7 =	2,950	...	421
	11	... 24 =	19,876	...	828
	12	... 19 =	195,835	...	10,307
	13	... 3 =	2,750	...	917
	14	... 1 =	1,700	...	1,700
	16	... 8 =	4,635	...	579
	17	... 14 =	22,491	...	1,606
	18	... 15 =	4,427	...	295
	19	... 9 =	6,820	...	758
	20	... 36 =	44,502	...	1,236
	21	... 1 =	1,000	...	1,000
	23	... 1 =	750	...	750
	24	... 1 =	1,750	...	1,750
	26	... 1 =	1,000	...	1,000
	27	... 1 =	2,250	...	2,250
	28	... 1 =	1,500	...	1,500
	30	... 1 =	1,500	...	1,500
Oct.	1				
	9				
	14	... 4 =	0	...	0
	24				
Nov.	4	... 1 =	225	...	225
	8	... 1 =	200	...	200
	16	... 1 =	600	...	600
	25	... 1 =	1,125	...	1,125
Dec.	12	... 1 =	470	...	470
	20	... 1 =	650	...	650
	23	... 1 =	300	...	300
	30	... 1 =	600	...	600

From the above list of the Dinoflagellate catches, and the accompanying curve (compiled from a total of 595 hauls), it is seen that the numbers rise from a very low point at the beginning of the year to a series of peaks in April, the highest of which is 5,704 per haul on the 9th, and in July a higher point (8,000) is reached, after which the numbers fall and keep generally at a lower level until the middle of September, when for a single day a very high average is attained, 10,307, the highest in the year. After this there is a very rapid fall, the



group is unrepresented in October,\* and the numbers keep irregular but low during November, December and January.

We have taken out separately from the statistics the figures in regard to *Ceratium tripos*, perhaps the most abundant species of Dinoflagellate in our district. It is

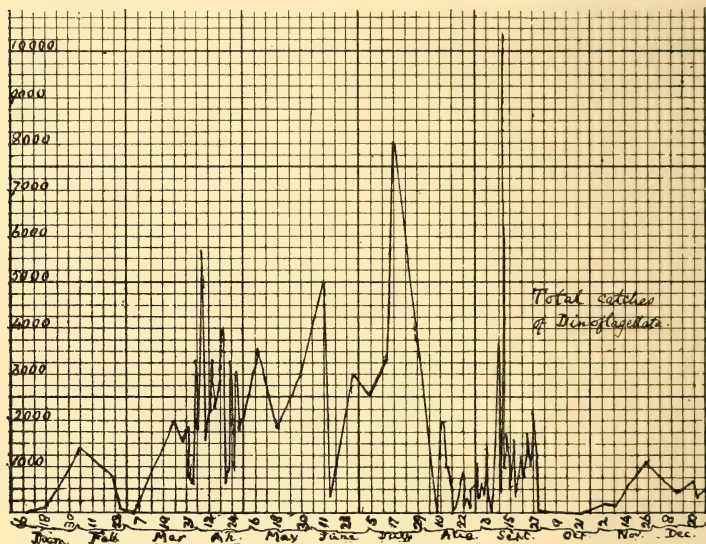


FIG. 6.

the more important that this should be done since a statement has appeared in a recent Blue-book (North Sea Fisheries Investigation Committee: Second Report (Southern Area) Part I, Cd. 3837, December, 1907, p. 172)

\* That is unrepresented in the series of gatherings from the Manx seas which we are considering; but members of the group were certainly present in the Irish Sea during the month, as two species of *Ceratium* were taken by the Lancashire Sea-Fisheries steamer at three Stations East of the Isle of Man, on October 7th. I do not suppose that Dinoflagellates are ever totally absent from the Irish Sea in any month of the year. Gough has recorded (Blue-book, Cd. 3837, p. 263) two species of *Ceratium* and three species of *Peridinium* as being rarely, or very rarely, present in the gatherings from the Bahama Bank Lightship in 1904.

which may, if not corrected, give rise to a false impression. The Marine Biological Association obtain gatherings once a fortnight from certain light-ships on the west coast, and one of these (on the Bahama Bank) is in our district of the Irish Sea. On the basis of these fortnightly gatherings (23) at this one station, in the year (1904) under discussion, Dr. L. H. Gough states in the official Blue-book that "*Ceratum tripus* was never seen at Bahama Bank," and again, "In the Irish Sea it [*C. tripus*] was rarest or even absent at the northern stations" [that is at the Isle of Man]. From such statements one would certainly gather that the organism in question was very rare, if not altogether absent from our district; but the fact is that it occurs practically all the year round in considerable abundance off the Isle of Man. *Ceratum tripus* is regarded as an oceanic species, and it is stated to have been found "very frequently" at Plymouth throughout 1904, but as no numbers are given in the detailed tables of the Blue-book (but merely crosses which indicate the presence, or in some cases letters to indicate relative abundance), it is impossible to compare results and to say whether our recorded figures for the Irish Sea are greater or less than the numbers of this organism found in the English Channel. And yet from the fortnightly gatherings from certain light-ships (one of which is in our district), in which certain organisms were not found, the far-reaching conclusion is drawn that "on the whole the Irish Sea may be said to be more neritic [i.e., showing a scarcity of oceanic species] than the Channel" (p. 169). That *may* be the case, but the conclusion can scarcely be based upon such statistics as the North Sea Fisheries Investigation Committee put forth in their official Blue-book. The facts in regard to this "oceanic" species *Ceratum tripus* are:—

(1) Their 23 gatherings in one year did not show the organism to be present.

(2) Our 650 gatherings in one year showed that it was present during eleven months, and was fairly abundant (up to 7,753 per haul) during most of the year.

In the following list we have separated the records of *Ceratum tripes* within Port Erin Bay from those taken in the open sea, and we give a curve for each locality (fig. 7). In most cases where hauls were taken in both places at the same time a larger number of individuals occurred within the bay; but on the other hand the largest number collected (7,753, on September 12th) was in a haul from the open sea.

Distribution of *Ceratum tripes*, per net,  
throughout the year:—

		Bay.		Open Sea.			Bay.		Open Sea.		
Jan.	18	...	100	...	—	June	11	...	1,500	...	—
Feb.	5	...	900	...	—		15	...	300	...	—
	22	...	750	...	—		27	...	2,000	...	—
	26	...	300	...	—	July	5	...	375	...	—
Mar.	26	...	500	...	—		12	...	2,500	...	—
	29	...	3,000	...	1,000		17	...	4,375	...	—
April	1	...	—	...	1,900		31	...	2,750	...	—
	2	...	—	...	2,000	Aug.	10	...	1,000	...	—
	4	...	—	...	550		12	...	2,000	...	—
	5	...	—	...	1,622		13	...	2,000	...	—
	6	...	500	...	—		14	...	1,000	...	—
	8	...	—	...	590		15	...	1,000	...	—
	9	...	2,750	...	1,119		16	...	500	...	—
	10	...	1,850	...	1,310		17	...	100	...	—
	11	...	—	...	1,125		19	...	375	...	—
	13	...	3,000	...	300		20	...	500	...	—
	15	...	300	...	633		21	...	37	...	725
	16	...	1,000	...	709		22	...	800	...	—
	17	...	3,000	...	—		23	...	325	...	142
	18	...	2,000	...	469		24	...	—	...	147
	19	...	—	...	792		26	...	—	...	75
	22	...	2,000	...	188		27	...	—	...	383
	23	...	1,000	...	250		28	...	400	...	716
	24	...	750	...	1,049		29	...	—	...	98
	25	...	250	...	412		30	...	300	...	—
	26	...	250	...	529		31	...	150	...	375
	27	...	1,125	...	659	Sept.	2	...	—	...	290
May	8	...	1,000	...	—		3	...	2,200	...	1,028
	18	...	1,750	...	—		4	...	—	...	289
	24	...	2,000	...	—		5	...	50	...	—

	Bay.	Open Sea.		Bay.	Open Sea.
Sept. 6 ...	—	373	Sept. 24 ...	1,500	—
9 ...	—	2,867	26 ...	750	—
10 ...	800	290	27 ...	1,250	—
11 ...	—	761	28 ...	1,000	—
12 ...	—	7,753	30 ...	1,500	—
13 ...	150	—	[Oct. ...	none	none]
14 ...	1,600	—	Nov. 4 ...	225	—
16 ...	1,250	425	8 ...	200	—
17 ...	—	1,000	16 ...	375	—
18 ...	875	357	25 ...	875	—
19 ...	900	460	Dec. 12 ...	325	—
20 ...	150	1,102	20 ...	600	—
21 ...	1,000	—	22 ...	300	—
23 ...	750	—	30 ...	600	—

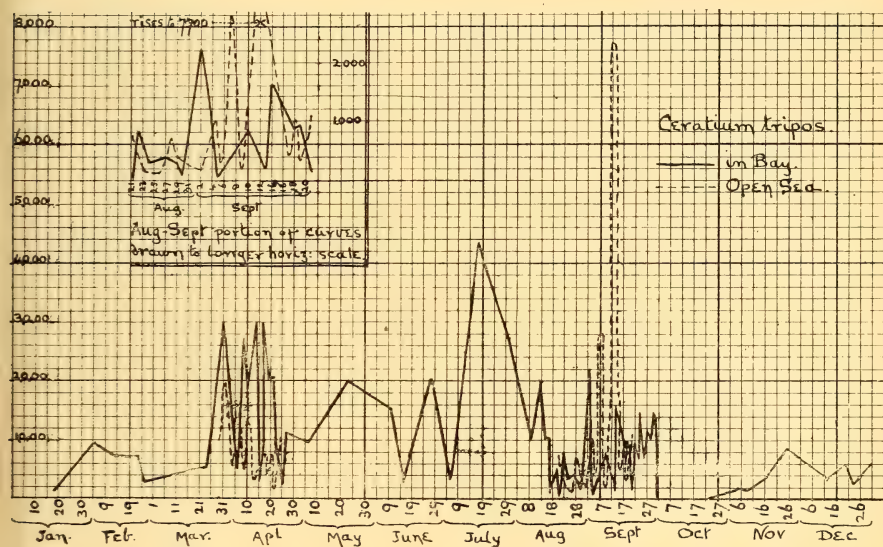


FIG. 7.

The general impression received from an inspection of these numbers is their constancy—a large proportion of them lie between 1,000 and 3,000; in the middle of April we see a run of 3,000, 1,000, 3,000, 2,000, 2,000, 1,000; in May, 1,000, 1,750, 2,000; in August, 1,000, 2,000, 2,000, 1,000, 1,000, and so on; and then again in November and December we have a run of hundreds, from



225 on November 4th to 600 on December 30th. All these numbers represent single hauls of a net.

The curve for the open sea can only be drawn for April and for portions of August and September; but during these periods it agrees fairly well with the curve for the bay. It shows the same kind of variations, up and down, although in April the humps do not reach so high and in September they go a great deal higher.

The curve for *Ceratium tripos* agrees in general with that for the total Dinoflagellates (fig. 6), but differs markedly from those both of Diatoms and Copepoda. The spring maximum in the Dinoflagellates is later than that of the Diatoms, but precedes that of the Copepoda. Then again the September hump of the Dinoflagellates is earlier than that of the Diatoms, and much earlier than the October maximum of Copepoda. On the whole the annual curve for the Dinoflagellates lies intermediate between those for Diatoms and Copepoda.

#### COPEPODA.

The following list shows the Total Copepoda, and the average per net for each day on which gatherings were taken throughout the year.

			Nets.	Total.		Average per Net.
Jan.	8	...	1 =	2,082	...	2,082
	18	...	1 =	1,551	...	1,551
Feb.	5	...	1 =	1,110	...	1,110
	22	...	1 =	30	...	30
	26	...	1 =	1,238	...	1,238
Mar.	4	...	1 =	1,825	...	1,825
	26	...	2 =	587	...	294
	27	...	1 =	476	...	476
	29	...	1 =	3,210	...	3,210
	29	...	4 =	4,370	...	1,092
April	1	...	8 =	26,495	...	3,312
	2	...	4 =	18,000	...	4,500
	4	...	9 =	1,135	...	126
	4	...	4 =	2,234	...	558
	5	...	5 =	2,247	...	449
	6	...	2 =	6,873	...	3,436
	8	...	10 =	4,135	...	413
	9	...	2 =	2,183	...	1,091

			Nets.	Total.		Average per Net.
April	9	...	12 =	42,915	...	3,576
	10	...	2 =	4,679	...	2,339
	10	...	15 =	18,349	...	1,223
	11	...	8 =	12,222	...	1,528
	13	...	2 =	21,550	...	10,775
	13	...	13 =	27,776	...	2,136
	15	...	1 =	9,280	...	9,280
	15	...	10 =	10,507	...	1,050
	16	...	1 =	11,600	...	11,600
	16	...	14 =	26,335	...	1,881
	17	...	1 =	15,659	...	15,659
	18	...	1 =	6,102	...	6,102
	18	...	13 =	32,250	...	2,481
	19	...	1 =	9,750	...	9,750
	19	...	11 =	43,203	...	3,927
	22	...	1 =	16,300	...	16,300
	22	...	11 =	47,955	...	4,359
	23	...	1 =	16,210	...	16,210
	23	...	11 =	82,799	...	7,527
	24	...	1 =	7,881	...	7,881
	24	...	11 =	109,272	...	9,934
	25	...	1 =	2,328	...	2,328
	25	...	14 =	53,823	...	3,844
	26	...	1 =	4,040	...	4,040
	26	...	14 =	57,554	...	4,111
	27	...	2 =	59,650	...	29,825
	27	...	17 =	48,360	...	2,845
May	8	...	1 =	1,045	...	1,045
	18	...	1 =	2,695	...	2,695
	24	...	1 =	6,505	...	6,505
June	11	...	1 =	13,610	...	13,610
	15	...	1 =	7,355	...	7,355
	27	...	1 =	15,450	...	15,450
July	5	...	1 =	6,680	...	6,680
	12	...	1 =	2,895	...	2,895
	17	...	1 =	7,930	...	7,930
	31	...	1 =	4,345	...	4,345
Aug.	9	...	1 =	9,450	...	9,450
	10	...	1 =	18,200	...	18,200
	12	...	1 =	9,700	...	9,700
	13	...	1 =	6,200	...	6,200
	13	...	1 =	1,851	...	1,851
	14	...	1 =	19,400	...	19,400
	15	...	1 =	14,700	...	14,700
	16	...	1 =	8,801	...	8,801
	16	...	1 =	640	...	640
	17	...	4 =	28,961	...	7,240
	19	...	4 =	5,499	...	1,375
	20	...	5 =	13,057	...	2,611
	21	...	2 =	114	...	57
	21	...	6 =	27,138	...	4,523
	21	...	5 =	11,070	...	2,214
	21	...	3 =	5,306	...	1,768
	22	...	1 =	2,600	...	2,600
	23	...	2 =	9,336	...	4,668
	23	...	3 =	4,811	...	1,604
	23	...	4 =	12,035	...	3,009
	23	...	5 =	9,842	...	1,968
	23	...	3 =	648	...	216
	24	...	3 =	27,086	...	9,028

		Nets.	Total.		Average per Net.
Aug.	24	...	5 = 84,577	...	16,915
	24	...	4 = 462	...	115
	24	...	7 = 7,079	...	1,011
	26	...	6 = 2,822	...	470
	26	...	6 = 52,981	...	8,830
	27	...	3 = 29,906	...	9,968
	28	...	6 = 23,187	...	3,864
	28	...	8 = 9,787	...	1,223
	29	...	5 = 54,850	...	10,970
	30	...	1 = 2,800	...	2,800
	31	...	6 = 2,825	...	470
	31	...	6 = 23,534	...	3,922
Sept.	2	...	6 = 20,403	...	3,400
	3	...	8 = 21,359	...	2,669
	3	...	3 = 2,325	...	775
	4	...	9 = 60,345	...	6,705
	4	...	5 = 14,820	...	2,964
	4	...	6 = 71,651	...	11,942
	6	...	9 = 1,779	...	197
	6	...	9 = 18,927	...	2,103
	6	...	9 = 23,390	...	2,599
	9	...	3 = 11,145	...	3,715
	10	...	7 = 14,579	...	2,083
	11	...	8 = 4,835	...	604
	11	...	8 = 57,882	...	7,235
	11	...	8 = 57,232	...	7,154
	12	...	8 = 3,034	...	379
	12	...	8 = 6,368	...	796
	12	...	3 = 81,531	...	27,177
	13	...	3 = 14,412	...	4,804
	14	...	1 = 3,595	...	3,595
	16	...	8 = 67,332	...	8,416
	17	...	7 = 14,025	...	2,003
	17	...	4 = 3,354	...	838
	18	...	8 = 55,595	...	6,949
	18	...	4 = 30,802	...	7,700
	19	...	9 = 43,877	...	4,875
	20	...	9 = 120,962	...	13,440
	20	...	9 = 2,434	...	270
	20	...	9 = 37,374	...	4,152
	20	...	5 = 136,561	...	27,312
	21	...	1 = 10,582	...	10,582
	23	...	1 = 18,450	...	18,450
	24	...	1 = 11,850	...	11,850
	26	...	1 = 2,197	...	2,197
	27	...	1 = 2,131	...	2,131
	28	...	1 = 8,325	...	8,325
	30	...	1 = 12,110	...	12,110
Oct.	1	...	1 = 1,045	...	1,045
	9	...	1 = 16,973	...	16,973
	14	...	1 = 27,790	...	27,790
	24	...	1 = 24,480	...	24,480
Nov.	4	...	1 = 5,587	...	5,587
	8	...	1 = 10,937	...	10,937
	16	...	1 = 3,853	...	3,853
	25	...	1 = 7,314	...	7,314
Dec.	12	...	1 = 1,724	...	1,724
	20	...	1 = 2,275	...	2,275
	23	...	1 = 2,403	...	2,403
	30	...	1 = 2,755	...	2,755

The Copepoda have two maxima in the year, the first in April and the second in September and October. The records start in January with about 2,000 per haul and keep below that level throughout February and most of March. During April they rapidly mount up with a series of successively higher records, with falls between, such as April 2nd 4,500, April 13th 10,775, April 16th 11,600, till the climax is reached on April 27th with 29,825. During May the numbers are low, 1,045 to 6,505, in June they rise somewhat, 13,610 on the 11th and 15,450 on the 27th, falling again in July to numbers between 2,895 and 7,930. August shows a series of rises with falls between, the tops being 18,200 on the 10th, 19,400 on the 14th, 14,700 on the 15th, 16,915 on the 24th, and 10,970 on the 29th. September begins at a low level, reaches 11,942 on the 4th, and, with falls between, 27,177 on the 12th, 13,440 on the 20th and 27,312 on the 20th, followed by 10,582 on 21st, 18,450 on 23rd, 11,850 on 24th, and 12,110 on 30th. October is also high, with 16,973 on the 9th, 27,790 on 14th, and 24,480 on 24th. November shows one high figure, 10,937 on the 8th; while December ranges from 1,724 to 2,755, the year's record ending very much at the same level at which it commenced in January.

The range in number of the Copepoda per net, 30 to 29,800, is considerable compared with that of some other groups.

The monthly averages of the Copepoda per net during this year are as follows:—

Jan.	...	...	1,816	July	...	...	5,462
Feb.	...	...	793	Aug.	...	...	5,496
Mar.	...	...	1,379	Sep.	...	...	6,514
Apr.	...	...	5,858	Oct.	...	...	17,572
May	...	...	3,415	Nov.	...	...	6,923
June	...	...	12,138	Dec.	...	...	2,289



The highest averages here (June and October) do not quite coincide with the maxima (April and September-October) in the previous treatment where the days were taken singly. The explanation is, of course, that although April contains a maximum far above that of June, it also contains in the earlier part of the month many low records that pull down the average when the month is treated as a whole. The maxima in high average bulk of catch extending over the month, but not in exceptional catches, are seen from this list to be in June and October, and especially in the latter, which agrees well with the curve on p. 274.

If we look now for the largest individual hauls of a single species of Copepod we find that they occur in April, August and September. The following are some of the more important of these:—

April	9—	<i>Pseudocalanus elongatus</i>	16,000
	9—	<i>Temora longicornis</i>	19,000
	17—	“ “	6,000
	22—	“ “	6,500
	22—	<i>Acartia clausi</i>	4,500
	22—	<i>Calanus helgolandicus</i>	4,600
	23—	<i>Acartia clausi</i>	8,000
	23—	<i>Calanus helgolandicus</i>	13,480
	24—	“ “	9,240
	24—	<i>Acartia clausi</i>	28,000
Aug.	26—	<i>Pseudocalanus elongatus</i>	8,700
	10—	<i>Oithona similis</i>	9,000
	13—	“ “	14,000
	17—	“ “	25,000
	24—	<i>Acartia clausi</i>	23,000
	24—	“ “	29,000
	24—	<i>Oithona similis</i>	21,000
	26—	<i>Acartia clausi</i>	16,500
	27—	“ “	24,700
	29—	<i>Pseudocalanus elongatus</i>	23,000
Sept.	4—	<i>Acartia clausi</i>	23,600
	4—	<i>Pseudocalanus elongatus</i>	36,000
	11—	“ “	21,000
	12—	“ “	33,600
	18—	“ “	25,000
	20—	<i>Oithona similis</i>	29,270

These also bear out the idea of maxima in April and in autumn, the latter being the more important one.

We shall now discuss the occurrence of some of the more important species of Copepoda separately.

#### CALANUS AND ANOMALOCERA.

The two large Copepoda, *Calanus helgolandicus* (Claus.) and *Anomalocera pattersoni*, Temp., are both regarded as oceanic species, and are both present in fair abundance in the Irish Sea. They are two of the most conspicuous objects in our plankton gatherings, and can readily be picked out with the eye and counted.

*Calanus* was present in our gatherings in 1907 during every month of the year from January 8th to December 30th. It was represented on nearly every occasion when hauls were taken, and in some cases when absent from one net it was taken in another gathering made on the same day, showing that the apparent absence was due to some imperfection in the sampling of the sea. When, then, we find that a species like this is not recorded from a particular haul at a time of year when gatherings are being taken once a week only, one is inclined to suspect from the appearance of the records at other times when the observations were more frequent, that if another haul had been taken that day or on an adjoining day the species would have been represented. The numbers as a rule are not large. They are low at the beginning of the year, and rapidly increase during April. We quote a few of what seem to us representative catches from each month. They are all from the surface nets when not otherwise stated:—

	Surface Nets.	0-10 faths.	Shear net.
Jan. 8 .....	14	—	—
Feb. 26 .....	3	—	—
Mar. 26 .....	2	—	—
April 1 .....	20	45	400
2 .....	330	150	6
11 .....	100	260	220
13 .....	135	150	360
16 .....	20	75	2,000

	Surface Nets.		0-10 faths.	Shear Net.
18 .....	1,600	600	1,200	—
22 .....	600	600	1,000	4,600
23 .....	1,500	1,250	—	4,000.
23 .....	1,600	2,500	1,700	—
23 .....	600	650	—	13,480
23 .....	360	380	—	9,240
24 .....	3,300	2,000	1,100	—

This is the climax; during May, June and July the numbers are lower.

July 31 .....	1,570	—	—	—
Aug. 9 .....	600	—	—	—
10 .....	2,500	—	—	—
21 .....	100	200	125	3,260
21 .....	2	2	40	140

During most of August and September the numbers keep low, although in former years we have, on occasions, taken very large hauls of *Calanus* in Port Erin bay in August and September.

Sept. 11 .....	35	40	675	—
12 .....	5	11	300	2,600
18 .....	1	1	255	—
19 .....	32	15	440	4,920

Then the surface hauls ran as follows:—September 24th, 500; September 30th, 20; October 9th, 200; October 14th, 2,700; October 24th, 475; November 4th, 30; November 8th, 85; November 16th, 8; November 25th, 12; December 12th, 2; December 20th, 0; December 23rd, 21; December 30th, 2. And so the year ended as it began, with low numbers, the highest figures being in April, and then again in Autumn; but the species is never absent.

It will be noticed that during April the larger numbers are sometimes in the surface nets and sometimes deeper; but that in September the weighted net at 10 fathoms contains most. The shear-net is not comparable with the others.

In the latter half of July, the “Ladybird” made a run up the west coast of Scotland, to Skye, and took a few

vertical plankton hauls in deep water. At the entrance to Loch Fyne, off Skate Island, in 104 fathoms, we got 13,000 adult *Calanus helgolandicus* in one haul on July 18th; and off Buidhe Island, near East Loch Tarbert, in 76 fathoms, we got 10,000 of the same species on July 27th, along with *Euchaeta norvegica*, *Nyctiphanes norvegica*, and other interesting forms. *Calanus* seems to be permanently present in the deep water of the west coast.

*Anomalocera*, on the other hand, first appears in our records on March 29th, and then only in the form of metanauplii (100, 170, and 30 in surface hauls off the Calf Island). Then on April 1st the deep net (10 fathoms) took 75 young, in their second-last stage of development. The same young stages were taken again on April 4th, 5th and 6th, with various nets, chiefly on the surface, and the first adults on April 9th, after which both adults and young continued to occur during the remainder of the month. The numbers on a few dates in April are:—

		Surface Nets.		10 faths.	
Adults	April 9	150	80	20	Station II.
Young	9	200	100	10	"
"	10	170	500	20	Station I.
"	10	500	750	400	Station II.
Adults	16	80	160	10	Station V.
Young	16	160	400	60	"
Adults	23	100	50	75	Station I.
Young	23	200	150	0	"
Adults	24	100	75	50	"
Young	24	100	75	0	"
Adults	26	9	10	37	"
Young	26	40	20	20	"

Shear, 500

*Anomalocera* does not occur in our records during May, June and July, but it must be remembered that during these months gatherings were only taken once a week. The species is recorded again on August 19th, and continues to be represented, in small numbers, by both adults and young, throughout August and September, and finally on November 8th. We have, however, noted its



occurrence in previous years in the open sea in January and February (Lane. Sea Fisheries Lab'y. Report, No. XIV, 1905, p. 35) ; and Mr. I. C. Thompson recorded an immense shoal between Douglas and Port Erin in May, 1888 (Proc. L. Biol. S., Vol. III, p. 183).

#### PSEUDOCALANUS.

It has seemed advisable to take out separately the distribution of the Copepod *Pseudocalanus elongatus*, which is present and fairly abundant throughout the year. It is represented in almost every gathering, and by high numbers (for a Copepod) in nearly every month. The greatest quantity for a single net rises in April to over 8,000 more than once, and in August reaches 16,000. But the maximum is seen from August 29th to September 18th, when the following very high numbers occur, with occasional lower ones between them:—23,000, 36,000, 21,000, 33,600, 15,000, 12,000, 11,000, 25,000, 12,800—each of these being the catch in a single net. These are, of course, the picked highest numbers of the year, and they all happen to represent hauls of the weighted open tow-net, which indicates that this species of Copepod is in greatest abundance a few fathoms below the surface. Quite apart from the exceptional hauls quoted above, we find that neither the surface nets nor the closing vertical nets worked in deeper zones caught nearly so many of this species as the weighted net ranging down to about ten fathoms. From the frequency with which similar nets and adjacent hauls give widely differing results, we are inclined to regard this as a species which is distributed irregularly in swarms, or patches of greater density.

#### MICROCALANUS.

The distribution of *Microcalanus pusillus*, G. O. Sars, in our district throughout the year is interesting. It



appears for the first time in our records late in August, and remains fairly constantly present but never very abundant throughout the autumn and winter until January, when it disappears. During the first few weeks it is only in the offshore hauls, appearing first out in mid-channel on August 24th in the Hensen and Nansen nets that were let down to 60 fathoms and hauled up vertically. As specimens were present in all the nets that were closed when they had been pulled up to 45 fathoms and were not present in the surface and other nets used above that level, it is evident that this Copepod was on its first appearance only in the deep water in mid-channel. It was encountered next on August 26th, in the weighted net hauled at 10 fathoms, on the inner edge of the Train Bank, some eight miles off land. On August 31st it made its appearance at Station I in the Hensen and Nansen nets hauled up from 24 fathoms, and in the weighted net from 10 fathoms—the latter having 350 specimens. It was also present on September 2nd and 3rd, under the same circumstances. On September 4th we again found it in mid-channel in the vertical nets which had been down to 60 fathoms; it was still not present in the surface nets nor in the inshore waters.

On September 6th, *Microcalanus* appeared for the first time inshore, at Station IV, off the Calf Island, but only in the Hensen and Nansen nets which had been closed at 8 and 15 fathoms respectively; it was not present in the surface hauls taken at the same time. It was next met with on September 11th, at Station V, south of the Calf Sound, inside the Wart Bank, when 100 specimens were taken in each of the two surface nets, 150 in the weighted net at 10 fathoms, and 5, 5, 5, 3, in the four vertical nets (2 Hensen and 2 Nansen) hauled from 20 up to 10 fathoms. It had evidently become

distributed by this time all through the water around the Calf Island. The following day, the species was present in nearly all the numerous nets worked at various depths down to 60 fathoms in mid-channel; and it then reached its climax in numbers, 2,000 in the net at 10 fathoms and 2,500 in an open tow-net attached to the shear-net at 20 fathoms. For some days after this *Microcalanus* was not taken in any of the nets, and then on September 21st it turned up for the first time in the surface gatherings taken across Port Erin Bay. It was present in these bay gatherings on October 1st (35) and 24th (100), November 8th (100), December 20th (80) and 23rd (50), and finally January 8th (50 specimens).

This record looks like the immigration of an oceanic species up the deep water of the mid-channel between the Isle of Man and Ireland, and then its gradual spread in late autumn into the shallower inshore waters and finally to the surface of the bay, where it remained throughout the winter.

#### CENTROPAGES AND TEMORA.

In the Blue-book (Cd. 3837, 1907, p. 175) on the International Fishery Investigations in the Southern Area during 1904-5, issued under the direction of the Marine Biological Association, the statement is made in regard to *Centropages hamatus* (Lilljeb.) that "in the Irish Sea it is a seasonal species occurring only in the summer."

We have no hesitation in saying, on the contrary, that this Copepod occurs in the Irish Sea all the year round. It is on our records for 1907 in every month, and is practically continuously present from January 8th to December 30th. The numbers are low at the beginning of the year, but reach 600 in one haul of the surface net by April 9th, and 1,300 on April 24th. Contrary to the

usual rule, this species seems more abundant on the surface than deeper—e.g.,

	Surface nets.		10 faths.	
April 18.....	100	100	0	Station II.
19.....	400	230	25	Station I.
19.....	190	112	50	Station II.
22.....	150	50	50	Station I.
23.....	100	50	0	Station IV.
24.....	1,300	800	75	Station I.
24.....	700	1,140	75	Station II.

These last two hauls show the highest numbers recorded for the year; they fall to 100 or under during May, June and July, recover to 600 by August 12th, drop again to the tens, or a hundred or two at most, later in August—when the larger numbers are sometimes in the deeper nets, e.g.—

	Surface nets.		10 faths.	
August 24 .....	40	20	225	Mid-Channel
24 .....	30	50	700	”
27 .....	30	20	100	Train Bank

During September, while the surface hauls remain relatively small the deeper nets occasionally get larger numbers, such as 420, 130, 230. On September 16th, however, at Station I, the numbers were:—surface nets, 255 and 47; weighted net (10 fathoms), 100. On September 19th a surface haul just outside the bay gave 240, and the following day successive surface hauls at Station I gave 165, 230, 165, 140. On September 23rd the record was 300, on 28th 100, in October 100, 150, 25, and in November and December the numbers drop to units. How a species with this record can be called “a seasonal species occurring only in the summer” is difficult to understand. The mistake can only be attributed to the attempt to draw conclusions from insufficient observations: twenty-three samples in the year is quite an inadequate treatment of the Irish Sea. There are various other statements in the Blue-book in

regard to the distribution of species in the Irish Sea which are contrary to our evidence; but it is impossible to go into all these cases now. Let us take *Temora longicornis* (Müller) as a final instance. As the result of the international observations, it is stated that "in the Irish Sea, it can be said to be a summer form"; while the fact is that on our records it occurs the whole year round from January to December, attains to high numbers in early spring, and remains fairly abundant into late autumn. It reaches close on 7,000 in one haul on April 1st, and 19,000\* on April 9th; and shows 1,280 and 1,600 up to the 23rd of September.

*Temora longicornis* seems to be equally abundant inside the bay and in the open sea, on the surface and in the deeper waters. Sometimes the large numbers are in the surface nets and at other times in the weighted net from below. This is one of the species that congregates in swarms, and so is occasionally caught in unusually large numbers. Of four similar hauls taken across Port Erin Bay on April 13th, the first two gave 875 and 620 and the last two 1,550 and 3,700 specimens of *Temora*. On the same date three hauls (two surface and one deeper) taken outside (Station III) gave 800, 850 and 900 specimens, which indicates an even distribution, but half an hour later a couple of miles away the same two surface nets gave 2,400 and 4,750 specimens; and moreover in this last case nearly all the *Temora* in the 2,400 were young, while in the second net the 4,750 were all adults, indicating a segregation of the stages in swarms. Many other examples of both agreement and divergence between the comparable nets could be given, and some may be seen in the Forms we have printed in this Report.

The records of some of the other species of Copepoda

\* These numbers quoted are, of course, the highest records.



on our Forms will probably well repay analysis, but these must now be left over for another occasion.

## CLADOCERA.

The two species of this group found in our district, *Podon intermedium* and *Evadne nordmanni*, occur mainly in summer, in a wide sense, ranging from the end of March to the beginning of October. Our first record of *Podon* is six specimens on March 26th, and the last is fifty on October 9th. *Evadne* begins with ten on March 29th, reaches 500 on April 9th, and ends with 50 on September 20th. Tens, twenties and thirties are common numbers in the records of both species, but sometimes the hundreds are reached. As a rule there is no great difference between surface and deeper hauls, and occasionally there is great constancy of results, indicating an even distribution:—e.g., on April 18th at Station II.

At Station II.	Surface nets.		10 faths.	Shear.	
<i>Podon intermedium</i> .....	150	150	—	—	—
<i>Evadne nordmanni</i> .....	100	100	150	50	50

On April 19th, in the bay, two similar surface hauls took 40 and 37 *Podon*, and 75 *Evadne* each; and at the same time, at Station II, ten miles off, the two surface nets took 40 *Podon* and 75 *Evadne* each. Other similar cases might be quoted; but on the other hand there are diverse hauls on other dates showing a very uneven distribution. The numbers during May and June are relatively high:—

<i>Podon</i> .....	190	80	150	100	100	150
<i>Evadne</i> .....	60	80	300	300	300	650

This is the highest point reached by *Evadne*, and this form is practically absent, or only occasionally present, during the latter half of August and parts of September. *Podon* reaches a climax (500) rather later, on August



13th, and soon after that drops to tens and even units, with an occasional appearance (August 31st, 200) in greater numbers. During most of September the group is but scantily represented; although neither species is ever absent for long, and occasional larger numbers occur—such as September 19th, off Calf Island, deep net, *Podon* 70, and *Evadne* 100; and September 20th, Station I, shear net, *Podon* 110 and 290, deep net 140; and, at the same time, inside the bay, 182. On September 23rd the ordinary surface net inside the bay took 550 *Podon*, and the following day 100, after which the numbers fall off rapidly.

#### TOMOPTERIS.

This pelagic worm occurs in our records occasionally throughout April, and then again in August, September, and onwards till the end of the year. It is not represented on our Forms during January, February, March, May, June and July; but these are the months when only weekly gatherings were made, and the question arises whether, if as many hauls had been taken then as in April and August, *Tomopteris* might not have been found.

Our first record of *Tomopteris onisciformis*, Esch., in 1907, is one specimen at Station II, in the weighted net (10 fathoms), on April 1st. It is never very abundant, being usually taken in ones and twos, and generally in the deeper nets—the vertical, the weighted, or the shear. This last net caught the largest numbers: it had 10 specimens on April 26th, 85 on September 19th, 95 and 65 on September 20th. The ordinary surface net inside the bay got 25 on August 15th, and 6 the following day, and the weighted net had 14 on September 19th and 12 on September 20th. From that time onwards to the end of

the year the numbers are under 10 at a time, generally one or two only.

From the records in the Blue-book (Cd. 3837, pp. 233, 241) it seems that this oceanic form occurs comparatively rarely at Plymouth and elsewhere in the English Channel—at Plymouth on three dates in 1904, and on two only in 1905. Unfortunately no numbers are given in the Blue-book, so no exact comparison can be made: but the probability is that—looking at our records of frequent occurrence over six months and of hauls extending up to 85 and 95 in a net—the species is very much more abundant in the Irish Sea than in the English Channel—why, then, is the Irish Sea described as the more “neritic” of the two?

#### OIKOPLEURA.

The common species of *Oikopleura* that occurs in our district (*O. dioica*) is also a form which deserves special notice. It occurs throughout the year, being present in every month, and represented in nearly every gathering. It is absent or rare in the case of the hauls taken on a few dates between August 24th and 28th, and then again on September 4th and 5th. With those exceptions, *Oikopleura* is one of the most constant of organisms at all times of the year, and, moreover, is usually present in quantities that range within narrow limits, so that it does not vary to the extent that some Copepoda and Diatoms do. In the winter months—December, January, February and March—the numbers taken are low, but from April to November inclusive quantities of a thousand or two per net are very frequently taken. The highest numbers occur in April, and they only reach 5,500 per net, so there is no marked maximum.

In some cases the numbers of *Oikopleura* remain

remarkably constant for several hauls, indicating a very general distribution through the water. For example, in one traverse of Port Erin Bay 2,780 were caught, and in the return traverse 2,030; then again, two adjacent hauls gave 3,840 and 3,600 respectively, and another pair of simultaneous hauls gave 2,250 each. But on the other hand, on another occasion, two successive traverses of the bay gave 5,050 and 2,480 respectively, and other examples of diverse results might be quoted from our records. But on the whole the impression received by an inspection of the Forms is that *Oikopleura* is more evenly distributed through the water than most of the other common organisms.

#### COMPARISON OF PORT ERIN BAY WITH THE OPEN SEA.

We have 136 surface hauls taken across Port Erin Bay throughout the year, from January 8th to December 30th. All months are represented, and nearly all weeks. January is the only month in which less than three weekly hauls were taken, and in all the remaining months except February, May and June there are at least four weeks represented. During April, August and September the observations were almost daily. In the open sea, however, surface hauls were only taken when the yacht was at work in parts of March, April, August and September. Mr. Douglas Laurie, who has kindly helped us by preparing some of the curves showing distribution, has made a comparison for April between the hauls taken (by himself with the assistance of others) and those that were being taken at the same time with similar surface nets from the yacht at the outside stations. The hauls from the yacht lasted 15 minutes each. Those taken in the bay consisted of a double traverse which occupied on

the average 20 minutes. Consequently the numbers recorded for the latter series have been decreased by one-fourth each, after which correction we consider that they are fairly comparable with the others.

We give here (fig. 8) an unsmoothed curve for the total plankton in the bay throughout the year, which shows well the great spring maximum in April and lesser elevations in June, August and October. When compared with the list of quantities given above for the

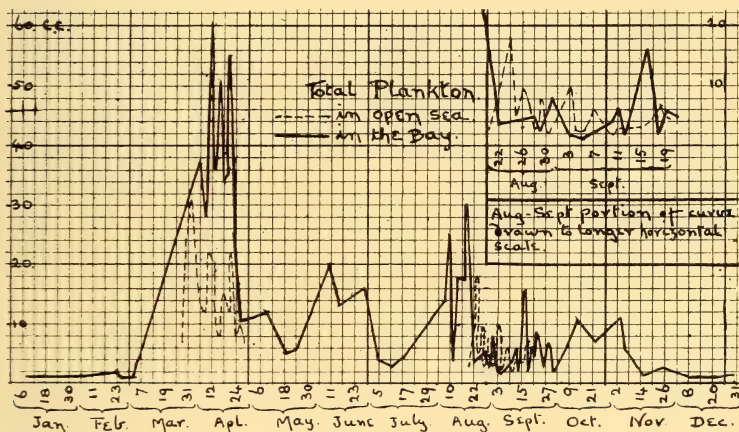


FIG. 8.

total plankton collected daily, or with the curve shown in dotted lines here (fig. 8) for the plankton of the open sea taken by itself in spring and in autumn, it will be noticed that the differences are not very great. The spring maximum is rather earlier in the open sea, and does not rise to such exceptional heights per net. In autumn (August and September) on the other hand the maximum for the open sea is, so far as our evidence shows, rather later than that for the bay, and again it does not rise to such heights. It is possible, however, that the total hauls in the open sea, per net, are kept



unduly low by the vertical nets being averaged along with surface and other quarter-hour horizontal ones. Occasionally the vertical nets (especially the Nansen) obtained very large catches, but over the whole they may have depressed the sea-average.

The great majority of the hauls in the bay were taken along a line crossing from S. to N. starting at the Life-boat slip and ending at Spaldrick Creek, and this was known as line I.; while a second traverse, line II, only occasionally made, was further out at the mouth of the bay, opposite the ruined breakwater.

Looking at the records for line I during April, when the hauls were most frequent, we find on the whole a decrease in Diatoms as the month goes on, associated with a rise in Copepoda. As a general rule we find that hauls rich in Diatoms tend to be poor in Copepoda, and *vice versa*; and our records show that the change may take place even within the hours of a day in the shallow water of the bay. For example, consider Form **25**, on April 13th, when the first pair (*a*) of hauls (A going North and B returning South) was taken (by Mr. Laurie) in the afternoon, while the second pair (*b*) was taken (by Professor Herdman) a few hours later in the early evening. Although *a* is a smaller haul than *b*, it contains more than three times as many Diatoms and nearly three times as many Copepod Nauplii and later larval stages, but less than half as many adult Copepoda. There had evidently, then, been a sudden decrease in the number of Diatoms (chiefly *Chaetoceros contortum*), and a certain amount of increase in the adult Copepods, and also in Sagitta, Crab Zoëas, and Gasteropod larvae.

On the other hand, we have an exception to the general rule that Diatoms and Copepoda do not abound together, on April 17th, when, compared with April 16th,



## 25.—Port Erin Bay, April 13th.

Net used .....	I.A	I.B	I.A	I.B
Depth in fathoms .....	0	0	0	0
Catch in c.cm. ....	26	24	26.5	45.5
	<i>a</i>		<i>b</i>	
<i>Biddulphia mobiliensis</i> .....	10,000	6,000	2,500	3,000
<i>Chaetoceros contortum</i> .....	82,000	33,000	500	9,000
„ <i>decipiens</i> .....	2,000	3,000	—	1,000
<i>Coscinodiscus concinnus</i> .....	5,000	5,000	6,500	3,500
<i>Rhizosolenia semispina</i> .....	4,000	1,000	—	500
<i>Thalassiosira nordenskiöldii</i> ..	5,000	—	—	—
„ <i>subtilis</i> .....	12,000	6,000	1,500	24,000
<i>Lauderia borealis</i> .....	5,000	1,000	—	500
<i>Ceratium fusus</i> .....	—	2,000	—	350
„ <i>tripos</i> .....	3,000	—	—	—
<i>Pleurobrachia pileus</i> .....	—	—	3	—
Medusoid gonophores .....	70	30	—	100
<i>Sagitta bipunctata</i> .....	3	4	14	10
Larval Polychaeta .....	1,000	500	2,000	650
“ <i>Mitraria</i> ” .....	500	—	100	300
Crab zoea .....	—	—	—	20
Mysis stage of Crangon .....	30	15	100	150
Other larval Decapods.....	100	100	—	—
<i>Podon intermedium</i> .....	25	15	100	—
<i>Evadne nordmanni</i> .....	25	15	300	—
<i>Calanus helgolandicus</i> .....	200	75	300	350
<i>Pseudocalanus elongatus</i> ...	1,500	1,500	3,700	2,150
<i>Temora longicornis</i> .....	875	620	3,700	1,550
<i>Centropages hamatus</i> .....	—	25	—	—
<i>Acartia clausi</i> .....	400	—	800	1,050
<i>Oithona similis</i> .....	675	475	1,000	300
<i>Paracalanus parvus</i> .....	175	130	—	—
Copepod nauplii.....	21,000	9,000	4,000	7,000
„ juv. ....	23,000	11,000	5,500	18,000
Barnacle nauplii .....	3,500	2,750	4,300	6,000
„ cypris stage .....	40	30	200	300
Gasteropods, larval .....	—	—	1,000	500
<i>Oikopleura</i> sp .....	1,500	1,800	2,500	3,000
Fish eggs—				
Rockling .....	—	2	—	2
Green Cod .....	1	—	—	—
Bib .....	2	—	1	—
Spotted Dragonet .....	—	—	1	—
Topknot .....	—	3	1	1
Sprat .....	—	—	2	7
Young fishes—				
Gadoid .....	—	—	1	1
Cottus .....	—	—	—	1

**32, 36.**—Port Erin Bay, April 16th.      April 17th.

Net used .....	I.A	I.B	I.A	I.B
Depth in fathoms .....	0	0	0	0
Catch in c.cm. ....	20	16	26	25
<hr/>				
<i>Biddulphia mobiliensis</i> .....	36,000	40,000	57,000	85,000
<i>Chaetoceros contortum</i> .....	3,000	1,000	8,000	6,000
" <i>decipiens</i> .....	—	—	5,000	5,000
<i>Coscinodiscus concinnus</i> .....	17,000	23,000	22,000	20,000
<i>Rhizosolenia semispina</i> .....	500	—	1,000	—
" <i>shrubslei</i> .....	—	—	2,000	—
<i>Thalassiosira nordenskioldii</i> .....	1,000	1,000	2,000	2,000
<i>Lauderia borealis</i> .....	—	—	—	500
<i>Ceratium fusus</i> .....	—	500	500	—
" <i>tripos</i> .....	—	1,000	—	3,000
<i>Peridinium</i> sp. ....	1,500	2,000	—	1,000
Medusoid gonophores .....	3	3	64	92
<i>Sagitta bipunctata</i> .....	10	10	30	15
Larval Polychaeta .....	300	300	2,100	920
"Mitraria" .....	—	—	500	—
Crab zoea .....	2	5	1	1
Mysis stage of Crangon .....	—	—	2	2
Nephrops, 1st stage .....	—	—	1	1
<i>Calanus helgolandicus</i> .....	150	50	240	130
<i>Pseudocalanus elongatus</i> .....	800	350	1,800	980
<i>Temora longicornis</i> .....	4,600	2,800	6,000	4,400
<i>Centropages hamatus</i> .....	100	50	16	8
<i>Acartia clausi</i> .....	1,250	800	625	720
<i>Oithona similis</i> .....	250	100	210	530
<i>Anomalocera</i> juv. ....	50	50	—	—
Copepod nauplii .....	6,000	11,500	40,000	25,000
"    juv. ....	10,000	12,000	15,000	16,000
Barnacle nauplii .....	1,000	350	2,100	920
"    cypris stage .....	200	200	80	80
<i>Oikopleura</i> sp. ....	2,250	2,250	2,850	2,400
Fish eggs—				
Rockling .....	—	4	—	—
Common Dragonet .....	2	3	1	—
Bib .....	1	2	—	1
Topknot .....	1	3	—	—
Sprat .....	—	1	—	2
Dab .....	—	—	—	1
Young fishes—				
Clupeoid .....	2	—	—	1
Gadoid .....	—	—	1	2

both Diatoms and Copepoda had increased considerably (see Forms **32, 36**).

Copepod Nauplii, however, seem to rise and fall in number on the same dates as the Diatoms; but on the

whole the Copepod Nauplii increase to a maximum on April 17th, when they are exceptionally numerous (see Form 36), and then fall off, so that the numbers at the end of the month are much the same as those at the beginning of the period under observation.

It is clear then that the problem of the periodic distribution of these various organisms is not quite so simple as might have been expected. There are probably three distinct factors at work:—(1) the periodicity of the stages in the normal life-history of the organism; (2) irregularities introduced by the inter-action of the

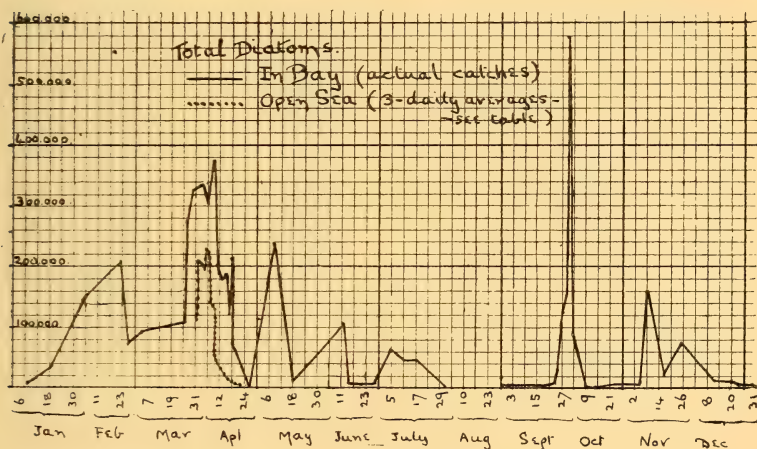


FIG. 9.

organisms, as when one group serves as food, or enemy of another; and (3) abnormalities as to either time or abundance caused by weather conditions, which may either prevent the normal or permit of an abnormal development of certain species.

Mr. Laurie has kindly drawn for us the accompanying curve (fig. 9) representing our results as to the Diatoms in the bay compared with those from the open sea.

It will be noted that the general character of the curves is similar, though the catch in the bay is consistently greater than that at sea. The less sudden diminution in the number of Diatoms in the bay from April 10th to April 17th will be observed, and the sudden drop which then follows, bringing the curves close together by the 23rd of the month.

The numbers of the total Diatoms from the hauls in the open sea during a month in spring are as follows:—

Date.		Hauls.		Average per haul.		3-day average.*
Mar. 29	...	4	...	45,162	...	—
April 1	...	3	...	103,333	...	111,998
2	...	2	...	187,500	...	209,055
4	...	4	...	336,333	...	198,722
5	...	2	...	72,333	...	230,111
8	...	3	...	281,667	...	142,133
9	...	5	...	72,400	...	136,133
10	...	6	...	54,333	...	56,578
11	...	4	...	43,000	...	44,175
13	...	6	...	35,192	...	32,811
15	...	4	...	20,240	...	23,465
16	...	8	...	14,962	...	16,651
18	...	4	...	14,750	...	13,237
19	...	4	...	10,000	...	8,349
22	...	4	...	297	...	3,746
23	...	6	...	942	...	551
24	...	4	...	415	...	661
25	...	6	...	625	...	1,780
26	...	4	...	4,300	...	3,880
27	...	7	...	6,714	...	—

\* By "three-day averages" is meant taking always the average of the three adjacent days upon which catches were made, *i.e.*, the average of the 1st, 2nd and 3rd, then of the 2nd, 3rd and 4th, then of the 3rd, 4th and 5th; and so on.

#### BAY DIATOMS THROUGHOUT THE YEAR.

A general inspection of the unsmoothed curve shows a well-marked maximum at the end of March and earlier part of April. The marked increase of Diatoms, and also of Copepod nauplii, towards the end of March is seen well in the surface hauls taken in Port Erin Bay on the following three dates:—



	March 26.	March 27.	March 29.
	12 c.c.	14.5 c.c.	18.5 c.c.
Total Diatoms =	220,000 ...	277,000 ...	326,000
<i>Biddulphia mobiliensis</i> .....	46,000 ...	50,000 ...	58,000
<i>Chaetoceros debile</i> .....	6,000 ...	8,000 ...	10,000
„ <i>deciens</i> .....	100,000 ...	150,000 ...	160,000
<i>Coscinodiscus concinnus</i> .....	64,000 ...	67,000 ...	75,000
Copepod nauplii .....	7,000 ...	27,000 ...	35,000

We have only quoted those species of Diatoms which are present in greatest abundance and which make up the bulk of the catch. All are included in the totals given. There is also an autumn maximum showing a very high peak at the end of September. Omitting, however, the single catch of September 30th (which is due in the main to *Rhizosolenia semispina*) the peak is reduced to less than one-third its former height. A remarkable feature of this September hump is the sudden character of its appearance and disappearance and its short duration (six days). An inspection of the temperature curve of the year for the water of the bay (fig. 10) shows that the sudden increase

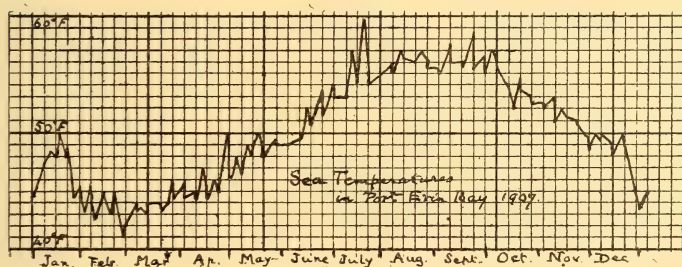


FIG. 10.

in the phytoplankton coincided with the maximum in temperature, and our weekly weather records at the Biological Station show at that same time a week of fine calm weather with easterly breezes (S.E. and E.S.E.). We have noticed the same phenomenon in previous years, both at Port Erin and on the west coast of Scotland, which seems to indicate that if weather conditions be suitable at

**122, 123.**—Port Erin Bay, October 1st and 14th,  
November 8th.    Surface.

	Oct. 1	Oct. 14	Nov. 8
Depth in fathoms .....	0	0	0
Catch in c.cm. ....	1·5	11·5	6
<hr/>			
<i>Biddulphia mobiliensis</i> .....	500	—	5,600
<i>Chaetoceros contortum</i> .....	2,750	—	300
" <i>debile</i> .....	500	—	—
" <i>decipiens</i> .....	3,500	—	3,000
" <i>sociale</i> .....	3,250	—	400
" <i>teres</i> .....	2,000	—	146,000
" <i>densum</i> .....	3,250	—	400
" <i>boreale</i> .....	750	—	—
" <i>subtile</i> .....	250	—	—
" <i>diversum</i> .....	750	—	—
<i>Coscinodiscus concinnus</i> .....	—	—	1,800
<i>Rhizosolenia semispina</i> .....	68,300	—	400
" <i>alata</i> .....	1,000	—	—
" <i>shrubsolei</i> .....	2,500	—	—
<i>Coscinodiscus radiatus</i> .....	500	—	1,000
<i>Bacteriastrum</i> sp. ....	250	—	—
<i>Guinardia flaccida</i> .....	1,000	—	300
<i>Streptotheca</i> sp. ....	—	—	100
<i>Ceratium tripos</i> .....	—	—	200
Medusoid gonophores .....	2	3	20
<i>Sagitta bipunctata</i> .....	5	190	56
<i>Tomopteris onisciformis</i> .....	—	8	1
Larval Polychaeta .....	—	250	—
"Mitraria" .....	—	250	100
Crab zoea .....	—	10	—
Mysis stage of Crangon .....	1	20	1
<i>Erythrops</i> sp. ....	—	—	—
<i>Microniscus calani</i> .....	—	50	—
<i>Calanus helgolandicus</i> .....	—	2,700	85
<i>Pseudocalanus elongatus</i> .....	220	8,100	1,350
<i>Temora longicornis</i> .....	—	70	8
<i>Centropages hamatus</i> .....	—	150	2
<i>Anomalocera pattersoni</i> .....	—	—	1
<i>Acartia clausi</i> .....	275	650	1,770
<i>Oithona similis</i> .....	485	12,600	6,170
<i>Paracalanus parvus</i> .....	30	3,300	1,450
<i>Microcalanus pusillus</i> .....	35	—	100
<i>Parapontella brevicornis</i> .....	—	30	—
<i>Isias clavipes</i> .....	—	190	1
Copepod nauplii .....	2,500	5,500	3,200
"    juv. ....	500	23,000	4,500
Gasteropods, larval .....	250	—	300
Lamellibranchs, larval .....	—	1,250	300
<i>Oikopleura</i> sp. ....	50	725	575

the end of autumn the phytoplankton may suddenly increase so as to constitute a second maximum in the year, the first being in spring; but that this possible maximum may be so modified in time and in amount by temperature and wind as to be unrecognisable. In 1906 it was very much more marked at Port Erin (see XXth Ann. Report, p. 53) than in 1907, and extended from September 20th to the end of the month.

The phytoplankton minimum for the bay occurs in August, no Diatoms being taken from August 9th to August 23rd (see curve), though nettings were taken on all days, except three, included between these dates.

As an example of a sudden change in the plankton we may compare the surface hauls taken in the bay on October 1st and 14th (see Form **122**). The total quantities of the two gatherings were 1·5 and 11·5 respectively; on the 1st, Diatoms were relatively abundant (over 91,000); by the 14th they had disappeared. But *Sagitta* and various larvae, and especially Copepoda, had greatly increased in number by the latter date. The adult Copepoda in all numbered only 1,045 on the 1st, while they reached 27,790 by the 14th; younger forms and Nauplii had also become much more abundant. By November, however, the Diatoms were back in quantity, as is shown by the third column (November 8th), and Copepoda have begun to decrease again.

#### BAY COPEPODA THROUGHOUT THE YEAR.

Copepoda are fairly abundant in Port Erin Bay from April to November inclusive, but there are considerable ups and downs, the number per haul varying often on successive days within very wide limits.

The curve (fig. 11) shows a gradual increase from the latter part of March through April, then (with depressions

in the beginning of May and the end of August) there are successive humps in June, early August and September leading to the maximum in October. This is followed by a rapid fall in November, and the minimum extends through December, January and February, the numbers commencing to rise again in March. On comparing the two curves it will be noticed that the April maximum for Copepoda is distinctly later than that for Diatoms, and that again the October maximum for Copepoda follows after the September increase of Diatoms. To a less extent throughout the rest of the year the two curves are complementary with the exception of late August and early September, when both are low.

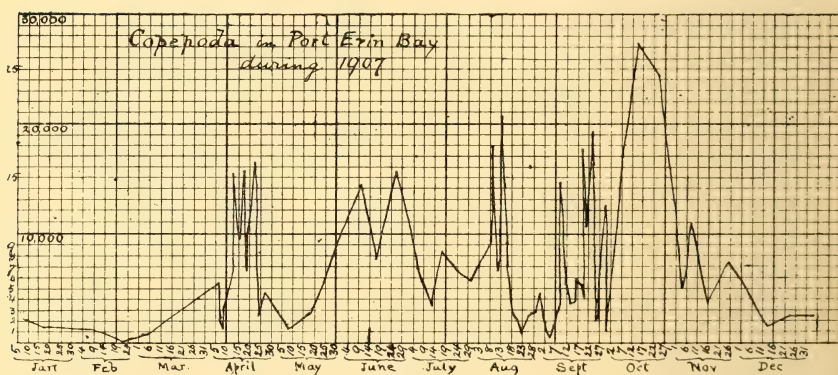


FIG. 11.

#### CIRRPEDE LARVAE IN BAY.

The Nauplius and Cypris stages of *Balanus* form an interesting study. The adult *Balani* are present in enormous abundance on the rocks of Bradda Head, and they reproduce in winter, at the beginning of the year. The Nauplii first appeared in 1907 in the bay gatherings on February 22nd, and increased with ups and downs to their maximum on April 15th, and then decreased until



their disappearance on April 26th. None were taken at any other time of the year. The "Cypris" stage follows on after the Nauplius. It is first taken in the bay on April 6th, rises to its maximum on the same day with the Nauplii, and was last caught on May 24th. Figure 12

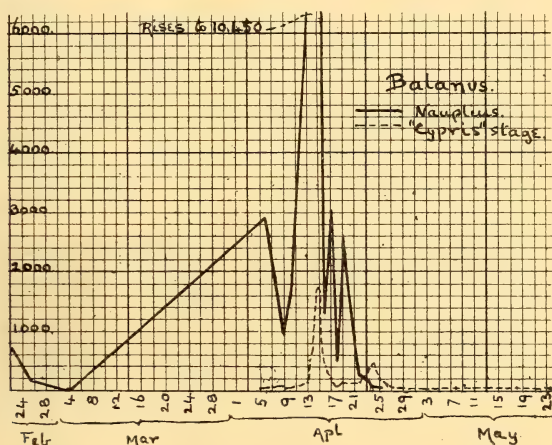


FIG. 12.

shows the curves for these two successive larval stages. It will be noticed how the "Cypris" curve keeps below that of the Nauplius, the maxima being 1,740 and 10,500 respectively. Probably the difference between the two curves represents the death-rate of the Balani during the Nauplius stage.

#### SAGITTA IN BAY.

The numbers of *Sagitta bipunctata* obtained in the bay catches throughout the year run as follows per haul:—Jan., 8; Feb., 1; Mar., 1; Apr., 8, 7, 24, 15, 20, 45, 15, 7, 61, 39, 20, 5, 4; May, 6, 100, 20; June, 95, 30, 15; July, 3, 35, 40, 425; Aug., 75, 100, 1,000, 200, 600, 1,800, 800, 700, 8, 54, 65, 63, 76; Sept., 16, 10, 40, 20, 20, 3, 26, 70, 50, 100, 10, 32, 50, 10; Oct., 5, 10, 190, 90; Nov., 324, 56, 1; Dec., 1, 8, 50. Fig. 13 shows the

curve drawn from these numbers, showing the more prominent humps in the height of summer and again in October-November. *Sagitta* is present throughout the year; it is most abundant in August, and the minimum occurs in winter (January to March).

We have not yet made a curve for the occurrence of *Sagitta* outside the bay, but so far as an inspection of the numbers shows the result would not differ materially from that given above. Those nets that are comparable give much the same run of numbers. As showing, however, the difference produced by a larger net of wider

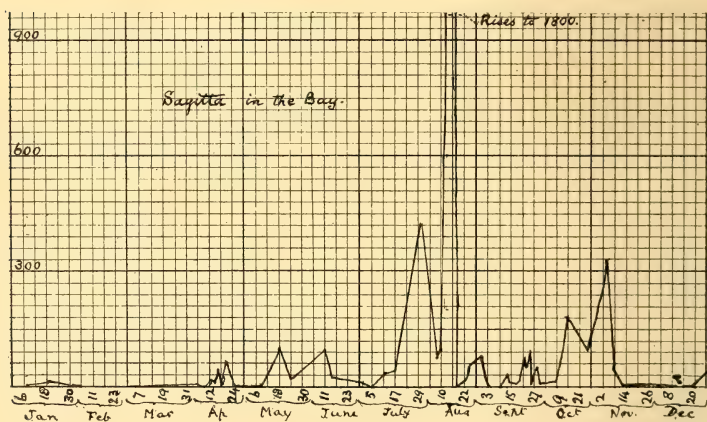


FIG. 13.

mesh, we find that during April, when the hauls with the ordinary tow-nets were giving units and tens, those taken at the same time with the shear-net ran into hundreds, as follows:—360, 123, 286, 310, 200, 200, 400, 400, 300, 800, 60. The fact, however, that the weighted tow-net, not invariably, but usually took a much larger number than the similar surface nets shows that *Sagitta* is usually more abundant in a zone of water below the surface, extending down to ten fathoms, and that consequently the

much greater numbers obtained by the shear net may be due not wholly to the size of the net and mesh but in part to the depth at which it was worked.

We give the following list as examples to show the difference in numbers of *Sagitta* caught by the surface (0 fathoms) and the weighted (10 fathoms) nets:—

0 faths.	10 faths.	0 faths.	10 faths.	0 faths.	10 faths.	0 faths.	10 faths.	0 faths.	10 faths.
6 ... 20	1 ... 30	1 ... 16	6 ... 22	2 ... 27					
1 ... 6	3 ... 11	4 ... 28	15 ... 85	24 ... 125					
1 ... 8	12 ... 27	1 ... 200	3 ... 17	— ... —					
0 ... 24	2 ... 40	1 ... 28	4 ... 240	— ... —					
2 ... 10	2 ... 23	2 ... 62	4 ... 30	— ... —					

We have occasional evidence from the closing nets that *Sagitta* is even more abundant in deeper water still. For example, on April 9th, at Station II, the surface net took one specimen, the weighted net at ten fathoms took eight, and the Nansen net, which had been worked through twenty to ten fathoms, took ten. On the other hand, we have a few cases in which *Sagitta* was more abundant on the surface, e.g., on September 9th, the weighted net at ten fathoms took eight, and the two surface nets took 25 and 86 respectively. As another example of the results obtained with different nets we quote the figures from September 19th, as follows:—the surface nets took two and six, the Hensen (hauled up vertically through twenty fathoms) two, the Nansen (vertical, twenty fathoms) one, the weighted net (ranging to ten fathoms) 126, and the shear net (about ten fathoms) 1,020 specimens.

#### OTHER LARVAL FORMS IN BAY.

Echinoderm larvae, Molluscan larvae and the Zoëa and Megalopa stages of crabs and some other larval forms are sporadic in their occurrence. They are only caught in abundance on rare occasions, and this is of course a

result simply of the reproductive phases in the life-history and has no connection with hydrographic conditions. The adults are gregarious and spawn at much the same time, the larvae hatch out in myriads at about the same time, and may then be caught in quantities. A notable example of this is the case described in the XXIst Annual Report of the Liverpool Marine Biology Committee, p. 37, of an enormous haul of *Zoëas* taken on April 1st, at Station III, in a very limited area—the same net hauled a couple of minutes before having caught none. Twenty-two thousand crab *Zoëas* were taken by the various nets on that occasion in about seven minutes.

Inside the bay the largest hauls of crab *Zoëas* are 200 and 300 on August 14th and 15th. They are practically absent from November to March inclusive, and during the remainder of the year occur rarely, in very small numbers.

“*Mitraria*” larvae are abundant in the earlier part of the year, and then again in winter—the range being from October to the end of April, with a maximum of 1,750 per haul in February. They are only occasionally found, and in small numbers, from May to September.

Polychaete larvae are more generally distributed and more abundant throughout the year. They reach a maximum in April, when the numbers per haul between April 10th and 23rd are, 260, 1,500, 2,650, 3,800, 600, 3,020, 1,330, 2,605, 700. They did not occur for some days in the middle of August, and the numbers were usually low in November, December and January, but throughout the rest of the year the general run of the figures is several hundreds per haul, occasionally reaching a thousand.



## FISH EGGS IN BAY.

Floating fish eggs (containing embryos) begin to make their appearance early in April in the bay and remain low in number (mostly under ten per haul) up to the middle of the month. There is a sudden rise in the Rockling eggs on April 18th (to 43 per haul), followed by a much more marked rise on the 22nd, and the numbers remain relatively high until the 25th (reaching a maximum of 500 per haul on the 23rd), after which they fall off rapidly and remain low in number and occasional in occurrence throughout the summer and autumn until September. The other fish eggs in the bay follow much the same course as the Rockling eggs, appearing at the same date, remaining low for the same period, rising at the same time, though to a much less degree—the maximum being 76 per haul—and then falling off rapidly to a low level which remains throughout the summer.

## VERTICAL DISTRIBUTION.

We have already shown above that our weighted open tow-net, ranging from about ten fathoms up to the surface during fifteen minutes, usually captured a larger quantity of plankton than the exactly similar surface nets hauled at the same time within a foot or two of the surface. This weighted net also, in most cases, caught more than the two vertical closing nets "Hensen" and "Nansen" (which, however, are not exactly comparable in size, either with the open tow-nets or with one another, see p. 230) hauled up as a rule through the zone of water from twenty fathoms to ten and then closed. In those cases, early in April, when either the Hensen or Nansen net showed a larger catch than the weighted net, the great bulk is seen

to be due to an excess of Diatoms in the vertical closing nets—thus showing that the protophyta are more abundant at that time in the lower layers of water. Larger organisms such as Medusae, Sagitta, Copepoda, Larvae and Fish Eggs are more abundant in the surface and the weighted nets—and more in the latter than in the former. We also find that, using similar open tow-nets, a net towed at a depth of a fathom or so catches more than one on the surface. At the time of the phytoplankton maximum in spring it seems from the evidence of these various nets that the Diatoms are present in an increasing ratio as one descends from the surface to at least twenty fathoms; but that the Copepoda and other larger forms are most abundant in a zone within ten fathoms of, but below, the surface—probably in some cases only a fathom or two below it. For example we may quote the following particulars from Form 28, April 13th, which is not an extreme case, as the Diatom maximum is then past:—

	Surface nets.	Weighted net.	Hensen.	Nansen.
		(10-0 f.)	(20-10 f.)	(20-10 f.)
Total Diatoms ...	6,500	6,650	11,000	96,000
Total Copepoda ...	1,970	1,880	3,180	66
				335

Here the Diatoms are clearly most abundant in the depths and thin upwards; while the Copepoda are more abundant above and most abundant of all a few fathoms below the surface. Many of the Forms about this date show similar results. Later on, when the Diatoms have become much less abundant, the vertical closing nets bring up very little from the lower zones of water and are surpassed by all the other nets, e.g.—

	Surface nets.	Hensen.	Nansen.	Weight.
April 24—Station I. ....	20·5	15·5	0·5	2
24—Station II. ....	7	15	3	5
25—Station III. ....	5·5	4·5	1·5	2
25—Station V. ....	8	7·5	1	2·5
26—Station V. ....	4	4·5	0·5	0·75
.....				
Aug. 21—Station I. ....	3	3	0·5	2
				6·5 c.c.

The last line shows that the same general proportions hold good in the latter part of August, when the catch is composed almost wholly of Copepoda.

In August some vertical hauls to the surface were made with the Hensen and Nansen nets out in deep water (60-70 fathoms), in mid-channel between the Isle of Man and Ireland, for comparison with similar hauls where the net was closed after having traversed some definite zone of water; and, as would be expected, the complete vertical hauls generally gave a larger result than the partial ones—except in a few cases where the haul was vitiated from the net apparently having gone so near bottom as to have taken in some mud stirred up by the weight.

Aug.	24—Station A.—Nansen,	60-50 faths.	=0·3;	60-35 faths.	=0·5 c.c.
	24—Station B.—	„ 60-45	„ =0·2;	60-0	„ =1 „
	26—Station I.—	„ 25-15	„ =0·25;	25-0	„ =1 „
	31—	„ — „ 24-10	„ =0·7;	24-0	„ =1·5 „
	31—	„ —Hensen, 24-10	„ =0·3;	24-0	„ =0·6 „
Sept.	3—	„ — „ 20-10	„ =0·25;	20-0	„ =0·75 „
	3—	„ —Nansen, 20-10	„ =0·5;	20-0	„ =0·7 „
	4—Station A.—	„ 60-30	„ =0·5;	60-0	„ =1 „
	4—Station B.—	„ 60-30	„ =0·3;	60-0	„ =0·75 „
	4—	„ —Hensen, 60-30	„ =0·4;	60-0	„ =0·5 „

There were also hauls on the last date through the zone 60-50 which showed still smaller amounts, 0·05 to 0·1 c.c. An attempt was made to discriminate more minutely between the zones on a few occasions—e.g. September 12th, in 65 fathoms.

	60-50	60-30	60-0	30-20	20-10	10-5
Hensen .....	0·1	0·1	0·25	0·1	0·15	0·25
Nansen .....	0·2	0·3	1·2	0·15	0·3	0·2

These and other hauls confirm the opinion we arrived at, from the use of the open horizontal tow-nets at different depths, that the most abundant zone of life is about ten fathoms, or between that and the surface—say, between ten and five fathoms.

Finally, we used the "Mill" water-bottle on several occasions to get samples from three exact depths, with the following results:—

Sept. 17th—	20 faths.	10 faths.	5 faths.
Total organisms .....	53	103	40
Total Diatoms .....	47	83	29
Total Dinoflagellata .....	3	12	6
Total Copepoda .....	3	8	5
Chaetoceros teres .....	1	3	1
„ densum .....	2	4	2
Rhizosolenia semispina .....	25	37	16
„ stolterfothi .....	12	26	9
Coscinodiscus radiatus .....	1	2	1
Ceratium furca .....	1	7	1
„ fusus .....	2	3	2
Sept. 18th—			
Chaetoceros teres .....	7	1	1
Rhizosolenia semispina .....	100	300	200
„ shrubsolei .....	1	1	2
„ alata .....	0	2	4
„ stolterfothi .....	1	1	2
Coscinodiscus radiatus .....	1	1	2
Total Dinoflagellata .....	11	32	9
Pseudocalanus elongatus .....	3	4	6
Total Copepoda .....	7	5	10
Copepod nauplii .....	10	20	30
Sept. 20th—			
Chaetoceros subtile .....	5	35	130
Rhizosolenia semispina .....	125	610	4,200
„ alata .....	1	6	40
„ shrubsolei .....	0	2	10
„ stolterfothi .....	1	4	10
Total Diatoms .....	132	672	4,470
Total Dinoflagellata .....	3	59	30
Copepod nauplii .....	1	18	60

These results are fairly consistent, and indicate a more abundant fauna in all groups at either ten or five fathoms than at twenty. On the 17th the fauna was at a lower level; the ten-fathom zone had over twice as much as the others, and the twenty was a little over the five. On the 18th also the fauna at ten fathoms predominated, but that at five fathoms came easily second. On the 20th the five-fathom fauna was much the most abundant and the ten-fathom came next. It seems as if during these days the centre of density was moving slowly upwards.

These observations should be repeated and extended,



but so far as they go they tend to establish the conclusion stated above as to the distribution of at least some elements of the plankton in zones of depth.

## HORIZONTAL DISTRIBUTION.

It is clear from an inspection of the Forms recording the 650 hauls now before us, that a much more detailed analysis than we can possibly give them before the publication of this Annual Report, will be necessary in order to arrive at any definite conclusions as to the relations between the results obtained horizontally at the different localities and dates. We recognise that we are far from having exhausted the information to be derived from these records; and the horizontal distribution, along with many other details of interest which we have noticed in the course of our work, must remain for some future occasion.

A mere inspection of the Forms shows in some cases close resemblances between adjacent stations (such as I and II) on the same day, or between adjacent days at the same station, and in other cases just as striking differences. How far these points of similarity and of divergence are normal and are fundamental, or how far they are due to wind, sun, and other weather conditions, or to tidal and other currents, will require detailed consideration.

We have several times been struck by the largeness of the hauls obtained, under very difficult conditions, in the strong tidal currents that race round the Calf Island. Such hauls are especially rich in Copepoda and other larger organisms of the plankton, and this observation is co-related with the well-known richness of the bottom and the littoral faunas in that same region, and agrees

with what has been recognised by naturalists for many years, that strong currents are favourable to a profuse development of animal life.

A further point that has struck us in the progress of this investigation is the obvious distribution of at least some organisms in shoals. This can occasionally be seen by the eye, when, for example, shoals of large Medusae are encountered which are so abundant for a limited area that on a calm day they may cover the surface like a tessellated pavement, and assume polygonal forms from mutual pressure. On other occasions our nets have evidently encountered swarms of Copepoda, of Cirripede Nauplii, of Crab Zoëas, of worm larvae or of other organisms. One might expect such results in the case of neritic forms, which are merely stages in the life-history of some gregarious organism; but the occurrence is by no means confined to such, it extends in our experience to oceanic organisms on the high seas, and this sporadic distribution in swarms has not been sufficiently taken into account by some writers who have treated of the distribution of the plankton in recent years.

The enormous quantities of the Diatom *Thalassiosira nordenskioldii*, Cleve, in our collections early in April (e.g. on April 4th 1,750,000, on April 5th 2,000,000, on April 8th 1,350,000 in single hauls) are a noteworthy feature. According to Gran ("Nordisches Plankton," Lief. III, xix, p. 16), this is a northern species found on the coasts of Northern Europe and the east coast of America. We have not met with it in the Irish Sea before. It might be argued that this was a case of a more northerly species carried down into our area by exceptional circumstances, or on the other hand the explanation may be that the Irish Sea is within the normal range of the organism, and that

special conditions have permitted of a quite exceptional development this year. In the latter case, however, it is curious that, considering all the plankton investigation that has been carried on at Port Erin and off the Lancashire coast during the last 20 years, the species has hitherto escaped notice. It appears to be present only very rarely at Plymouth and elsewhere in the English Channel (Blue-book, Cd. 3837, p. 228, 236, &c.).

### CONCLUSIONS.

We have expressed our opinions freely, both on general questions and on matters of detail, where they occurred to us in the course of writing the preceding pages, but it may be convenient to have summarised here the main conclusions at which we have arrived.

1. It is clear that many of the great seasonal variations in the plankton are not due to changes in the sea-water such as are recognised in hydrographic observations, but are caused simply by the normal sequence of stages in the life-histories of organisms throughout the year. No amount of "hydrographic" change in the water will determine the presence of Echinoderm larvae at a time of year when they are not produced, nor of Crab *Megalopas* when they do not naturally occur.

2. Three factors, at least, seem to us to require recognition as contributing to the constitution of the plankton from day to day throughout the year:—

(1) The sequence and periodicity of the stages in the normal life history of the organisms;

(2) Irregularities introduced by the inter-action of the organisms, as when one group serves as the food, or enemy, of another;

(3) Periodic changes and abnormalities of either time or abundance caused by the character of the sea-water or by weather conditions which may either determine or prevent the normal or permit of an abnormal development of certain species.

The appearance of swarms of Balanoid Nauplii, followed after an interval by the "Cypris" stage, is an example that comes under the first head. The disappearance of Diatoms when used as food by the increasing swarms of Copepoda and other Crustacea, both larval and adult, and of the Copepoda in turn when eaten by the developing post-larval fish, are changes falling under the second head. The great increase in the number of Diatoms in spring when the physical condition of the sea-water has become favourable, the enormous development of Dinoflagellates which may take place suddenly in autumn under unusual weather conditions, the almost total suppression of a group such as the Medusae in some localities in an unusually stormy summer, and the immigration of a species or a group of species from the open ocean or from a neighbouring sea-area as the result of variations in the hydrographic conditions, are all examples that may be classed in the third category.

Two, or all of these factors may, however, be at work together, and so the explanation of any particular change may be a very complicated problem. The increased development of a group, or the immigration of a species, may so disturb the balance of nature as to be followed by unusual changes in other groups.

3. Lists compiled from our results and curves drawn from these lists show that, as a consequence of the above factors, certain groups and certain prominent species differ from one another greatly in their relative abundance throughout the months of the year.



4. Thus, the Diatoms take on an enormous development in early spring, and reach their maximum in April, then die down during the summer, and may rise again to a second but much less important and less constant maximum in autumn. It must be borne in mind, however, that the species, and to some extent the genera, that form the autumn increase (*Chaetoceros subtilis* and species of *Rhizosolenia*) are quite different from those present in spring (*Chaetoceros contortum* and species of *Thalassiosira*).

5. The Dinoflagellata rise to a maximum later than the Diatoms, and may have a second period of sudden increase in the autumn if weather conditions are favourable.

6. The Copepoda attain to their greatest development in early summer after the Diatoms have died down, and again in late autumn (October) they follow the phytoplankton. As a rule a haul rich in Copepoda has few Diatoms, and *vice versa*; but the Copepoda do not, like the Diatoms, present great maxima and marked depressions. Even when both groups are present in the plankton we frequently find that they are in different zones; for example, in some of the April hauls in 1907 the Diatoms were markedly on the surface and the Copepoda below, while later in the year these positions were reversed.

7. The distribution of particular Copepoda (*Calanus*, *Anomalocera*, *Microcalanus*, *Centropages*, *Temora*, etc.) has been discussed, and for the full results we must refer to the body of this report. *Calanus*, *Centropages* and *Temora* are present throughout the year; *Anomalocera* appears in our district in spring; *Microcalanus* in late autumn.

8. Similarly the conclusions arrived at in regard to the distribution of *Sagitta*, *Tomopteris*, the Cladocera, *Oikopleura*, Cirripede Nauplii, and various other larval

forms and fish eggs are given in the preceding pages and need not be repeated here.

9. The Irish Sea contains a surprising number of what are usually regarded as "Oceanic" species—not merely as occasional visitants, but as normal and continuous constituents of the plankton during a great part of the year. Amongst these may be mentioned *Chaetoceros densum*, *Coscinodiscus radiatus*, *Rhizosolenia semispina*, *Ceratium tripos*, *Peridinium* sp., *Tomopteris onisciformis*, *Sagitta bipunctata*, *Pleurobrachia pileus*, *Calanus helgolandicus*, *Anomalocera pattersoni*, *Acartia clausi*, *Oithona similis*, and *Oikopleura dioica*. Some of these oceanic species seem, so far as we can judge from the published records, to be more abundant and more continuously present round the Isle of Man than they are even in the western part of the English Channel.

10. We have evidence from our closing vertical nets that the zone of most abundant life is not on the surface but is generally a few fathoms below—say, usually, between 5 and 10 fathoms. Samples of water from 5, 10 and 20 fathoms obtained with the "Mill" water bottle support the above statement. But this conclusion was arrived at, and could be established, quite apart from the evidence of the vertical nets, from a comparison of the results obtained by the weighted and surface open horizontal tow-nets.

11. At the time of the Diatom maximum in spring, however, our closing vertical nets showed that these Protophyta are more abundant in the deeper zones than at the surface, and increase in density downwards to at least 20 fathoms.

12. In the case of some groups, e.g. Cladocera and *Oikopleura* sp., the distribution is sometimes remarkably regular, the same numbers being taken simultaneously

by comparable nets at localities up to ten miles apart; but on the other hand even with these same groups there may, on other dates, be very diverse hauls indicating an uneven distribution.

13. Some species, and some groups of neritic larvae markedly congregate in shoals, and this also adds to the unevenness of the distribution.

14. The horizontal distribution of the plankton is consequently liable to be very variable and irregular, and although its characteristic constitution at different times of the year may be described, it is very doubtful whether any numerical estimates can be framed which will be applicable to wide areas.

15. It is clear that samples taken quarterly, monthly or even fortnightly are quite inadequate to convey a correct idea of the constitution and changes of the plankton of a sea-area in any detail; and, consequently, conclusions ought not to be drawn from such insufficient observations.

16. Our samples, taken weekly throughout the year, and almost daily during the three most critical months, give by no means too much information, but will probably suffice to enable us to make that detailed comparison between adjacent localities and dates which we hope to publish in the next Report with a view of determining the representative value of such periodic samples.





# L.M.B.C. MEMOIRS

## No. XVI. CANCER.

(THE EDIBLE CRAB.)

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## INTRODUCTION.

CANCER is a genus which has a world-wide distribution. Only one species, however, is found in Europe, viz., *Cancer pagurus*, the subject of the present memoir.\* This species is found on almost every part of the coasts of Europe from Norway to Greece, and it is particularly abundant on the shores of North-West Europe (France, Germany and the British Isles).

*Cancer pagurus*, the edible crab, has been chosen as the subject of the present memoir partly on account of its economic importance, and also because, as a type for dissection, it is easily procurable and is of a convenient size. The account given below, however, may be applied with very few alterations to any of the brachyurous Decapod Crustaceans, such as the common shore crab (*Carcinus*) or the swimming crab (*Portunus*).

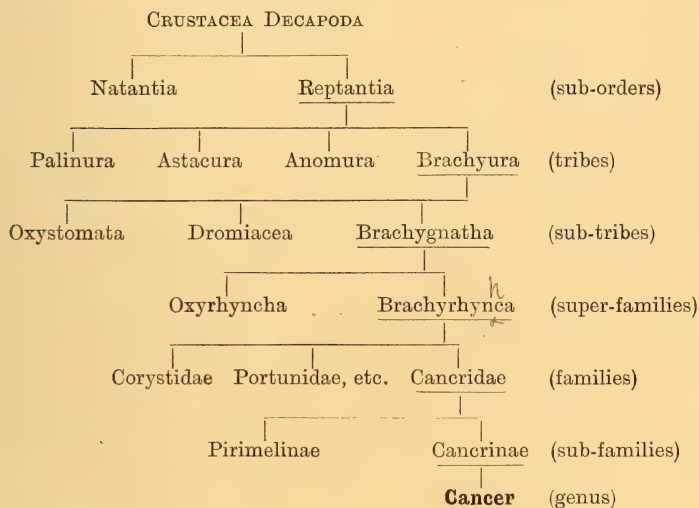
The edible crab is found in great abundance on the coasts of the British Isles, especially on those parts which are rocky, and gives rise to an important fishing industry. The large crabs live in fairly deep water, but the young representatives of this species may be readily obtained between tide-marks. Cancer is mainly carnivorous in its habits and feeding. It is particularly fond of dead fish, and it probably also feeds on other Crustaceans in a small degree. There is, however, no evidence to show that it has cannibalistic instincts. (For further particulars with regard to habits, distribution, crab fishery, &c., see section on Economics.)

*Cancer pagurus* was first named by Linneus, who established both the genus and the species. In his

\*The investigation has been assisted by a grant of £25 from the Board of Agriculture and Fisheries, and the expense of producing the lithographed plates has been met in part by a grant of £30 from the "Treasury Grant for Research" of the University of Liverpool.

"Histoire naturelle des Crustacés," Milne-Edwards named it *Platycarcinus pagurus*. This latter name appears to have been retained in many continental works up to quite recent years.

I have followed the classification of Borradaile,\* and I give below a table compiled from the results of his work.



The main characters of the various divisions of the Decapod Crustacea are given below.†

**NATANTIA.**—Rostrum well developed and compressed.

Body compressed. First abdominal somite equal to rest. Stylocerite present. Second antennal scale large. In the legs basis and ischium never fused, and one fixed point in the carpopodal articulation. Male genital opening arthrodial. Abdominal limbs 1-5 well developed and used for swimming.

\* Borradaile, L. A. "On the Classification of the Decapod Crustaceans." *Ann. and Mag. Nat. Hist.* (7), Vol. XIX, June, 1907.

† These characters are abstracted from Borradaile's paper.

REPTANTIA.—Rostrum reduced or absent, depressed if present. Body depressed. First abdominal somite smaller than rest. Stylocerite absent. Second antennal scale reduced or absent. In the legs generally a basi-ischium, and two fixed points in the carpo-propodal articulation. Male genital opening coxal and sternal. Abdominal limbs 1-5 reduced or absent, and not used for swimming.

The four tribes belonging to the Reptantia are divided into two groups.

I. Third legs like the first. Abdomen macrurous. Gnathobases of second maxillae narrow. Exopodites of maxillipedes with lash directed forward. Gills numerous.

(1) PALINURA.—Carapace fused to epistoma. Rostrum small or absent. Inner lobes of second maxillae and first maxillipedes reduced. Body depressed.

(2) ASTACURA.—Carapace free from the epistoma. Rostrum large. Inner lobes of second maxillae and first maxillipedes not reduced. Body sub-cylindrical.

II. Third legs unlike the first, never chelate. Abdomen rarely macrurous. Gnathobases of second maxillae broad. Exopodites of maxillipedes with lash directed inward. Gills few.

(3) ANOMURA.—Carapace not fused with epistoma. Last thoracic sternum free, its legs differing from the others. Abdomen anomurous. Movable antennal scale. Third maxillipedes narrow.

(4) BRACHYURA.—Carapace fused with epistoma. Last thoracic sternum fused with rest, its legs like the others. Abdomen brachyurous. No movable antennal scale. Third maxillipedes broad.



The following are the sub-tribes of the Brachyura:—

OXYSTOMATA.—Mouth-field prolonged forward as a gutter. No female first abdominal limbs. Gills few. Female openings sternal.

DROMIACEA.—Mouth-field square. First abdominal limbs present in female. Gills many. Female openings coxal.

BRACHYGNATHA.—Mouth-field square. Female openings sternal. No first abdominal limbs in female. Gills few.

The Brachygnatha are divided into two superfamilies.

OXYRHYNCHA.—Front part of body narrow. Distinct rostrum. Body more or less triangular. Orbits incomplete.

BRACHYRHYNCHA.—Front part of body broad. Rostrum reduced or wanting. Body oval. Orbits complete.

The Brachyrhyncha are sub-divided into fourteen families. I give here the chief characters of the one family—the Cancridae.

CANCRIDAE.—Marine crabs with the branchial region not greatly swollen. Carapace broadly oval or hexagonal. Rostrum often wanting. Orbits complete. Male openings coxal. Second antennal flagella short. First antennae folded lengthwise. Inner lobe on the endopodite in the first maxillipedes wanting. Legs generally not adapted for swimming.

The two sub-families of the Cancridae are as follows:—

PIRIMELINAE.—Carapace hexagonal. Epistoma sunken.

CANCERINAE.—Carapace broadly oval. Epistoma not sunken.

## EXTERNAL CHARACTERS

(Pl. I, figs. 1, 2, 3).

The whole of the exterior of the animal is covered by a thick continuous chitinous exoskeleton or shell, which is highly calcified except between the movable somites of the abdomen and between the movable podomeres in the appendages.

The body may be conveniently divided into an anterior region—the Cephalon, a middle region—the Thorax, and a posterior region—the Abdomen. As in all the Decapoda the Cephalon and Thorax are fused to form the Cephalothorax.

The Cephalothorax is by far the largest portion of the body, and is the only part seen from the dorsal surface. The Abdomen is much reduced and is a flap-like structure closely applied to the ventral region of the cephalothorax between the bases of the walking legs.

There is every reason to believe that the crabs and their relatives have arisen from primitive Crustaceans having a body divided up into a number of movable segments or somites. Extreme specialisation has taken place, especially in the cephalothoracic region, and it is in the Abdomen that one sees the nearest approach to this primitive external segmentation. A careful examination, however, reveals the fact that there are *five* somites in the cephalic region, *eight* in the thorax and *six* in the abdomen—*nineteen* in all.

Before entering on a description of the more complex parts it will be useful to examine the structure of a typical abdominal somite.

The *third abdominal somite* of the female may be taken as a type (see text fig. 1).

This somite is flattened dorso-ventrally. On the

dorsal side there is thick and highly calcified exoskeleton, but the ventral wall is membranous.

The dorsal wall consists of a median portion—the **tergum** (text fig. 1, *t.*)—which is continued into two broad lateral portions—the **pleura**. The median ventral wall is known as the **sternum**, and from each of the outer portions of the sternum arises an appendage. Between the point of attachment of each appendage and the pleuron the ventral wall is known as the **epimeron**.

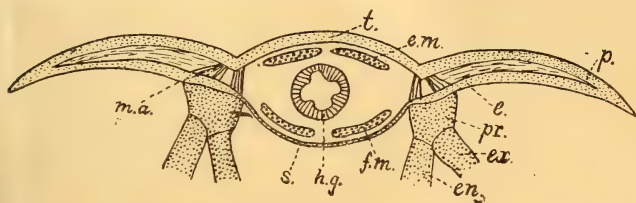


FIG. 1.—Diagrammatic section through female abdomen.

- |  |                                    |
|--|------------------------------------|
| <i>t.</i> = tergum.                        | <i>m.a.</i> = muscles of abdominal |
| <i>p.</i> = pleuron.                       | appendage.                         |
| <i>s.</i> = sternum.                       | <i>h.g.</i> = hind gut.            |
| <i>e.</i> = epimeron.                      | <i>pr.</i> = protopodite.          |
| <i>e.m.</i> = extensor muscles of abdomen. | <i>ex.</i> = exopodite.            |
| <i>f.m.</i> = flexor muscles of abdomen.   | <i>en.</i> = endopodite.           |

The segment is connected with the two neighbouring segments by a thin uncalcified part of the exoskeleton—the **arthrodial membrane**. This allows of free movement between the segments. Each segment articulates with the one in front by means of a pair of hinges placed at the outer and anterior part of the pleuron at each side.

The appendages will be described in detail later.

## CEPHALOTHORAX.

### 1. Carapace.

The terga and pleura of the cephalothorax are fused to form the large Carapace. This is a broad shield the width of which is about  $1\frac{1}{2}$  times as great as the length.

Instead of taking an even sweep downwards the carapace passes outwards almost horizontally and then suddenly bends inwards and passes down to the bases of the walking legs. An examination of a rough section of the animal will show that at the base of the legs the carapace turns suddenly upwards and is continuous with the membranous wall of the spacious **Branchial Chamber** (Pl. IV, fig. 56, *br. ch.*). The space between the ventral part of the carapace and the base of the legs is so very small, and moreover is so well guarded by long setae that no water can enter the branchial chamber at this border, as is the case in the *Macrura*. There are, however, two openings into the branchial chamber—the small *posterior inhalent branchial aperture*, above the coxopodite of the last pereopod, and the larger *anterior inhalent branchial aperture*, situated immediately in front of the coxopodite of the chela. The ventral part of the carapace turns forward in front of the latter opening, and passing around the mouth it fuses with the pre-oral cephalic sterna. The portion of the carapace which passes around the mouth is turned inwards at each side to form a chamber which lies immediately in front of the Branchial Chamber. This may be called the **Pre-branchial Chamber**. Its roof is membranous and is fused on its inner side with the epistoma and with the endopleurites of the two post-oral cephalic somites, and probably represents the epimera of the third, fourth and fifth cephalic somites. The Pre-branchial Chamber will be described in detail in the section on Respiration.

Both the dorsal and the inflected portions of the lateral region of the carapace were designated the “branchiostegite” by Milne-Edwards because they enclose the branchial cavity.

Anteriorly the dorsal surface of the carapace is



bounded by a median portion between the orbits and two lateral portions. Similarly the posterior boundary consists of a median portion and two lateral portions. So that we may speak of these borders as the anterior, antero-lateral, posterior and postero-lateral respectively.

The **Anterior Border** is situated between the orbits. The *rostrum*, which occupies the median portion of this region, consists of a median and two lateral lobes. It is continued ventrally as a median plate which separates the two cavities in which are lodged the eye peduncles. Each of the lateral lobes of the rostrum passes downwards as the *supraciliary lobe*, which fuses with the anterior and inner region of the second antenna (Pl. III, fig. 20, *S.L.*). Passing outwards from the rostrum the anterior border of the carapace divides at each side into the supra-orbital and infra-orbital portions which form the boundary of the orbit. On its inner side the supra-orbital edge has the prominent *supra-orbital lobe* which is close to the lateral lobe of the rostrum. The inner boundary of the orbit is fused with the outer portion of the second antenna.

The **Antero-lateral Borders** form an arc of a circle the centre of which is at the junction of the two outer grooves bounding the epibranchial region of the carapace (see below). Each antero-lateral border is divided up into nine lobes by well-defined ridges. There is no definite distinction between the antero-lateral border and the postero-lateral border, but the latter may be said to commence at the posterior end of the ninth lobe. There is also a feebly marked lobe on the outer portion of the postero-lateral ridge.

The **Postero-lateral Border** passes backwards and inwards. This border is well rounded and not so clearly defined as the anterior and antero-lateral borders.

Immediately in front of this border there is the

*postero-lateral ridge*, which is continuous on its outer side with the antero-lateral border. At its outer edge it is coincident with the postero-lateral border, but as it passes inwards it becomes quite distinct from the latter and dies away near the median line in front of the posterior border.

The **Posterior Border** of the carapace is horizontal, and is continuous behind with the tergum of the first abdominal segment.

#### Areas of the Carapace. (Text fig. 2.)

The dorsal surface of the carapace is divided up by means of small depressions into areas.

The *Cervical groove* (*C. gr.*) separates the cephalic region of the carapace from the thoracic region. This groove is seen as a transverse median depression a little more than half way down the carapace. The width of this median groove is almost equal to the distance between the two supra-orbital lobes.

At each of its outer edges the median groove is continuous with a well-marked depression which commences at the posterior end of the fifth lobe of the antero-lateral border. This depression is curved, the convexity being in front. The median groove and its two lateral extensions together form the cervical groove.

The Cephalic portion of the carapace is divided into the Facial and Gastric regions.

The Facial region is separated from the rest of the cephalon by a faint transverse depression near the front of the carapace. The outer ends of the depression bend forward and terminate on the second lobe of the antero-lateral border. This region is divided into a median **Frontal** region (*Fr.*) and two lateral **Orbital** regions (*Orb.*).

The Gastric region is bounded behind by the

Cervical groove, and is composed of a median triangular portion having the apex pointing backwards and two lateral portions which end at the antero-lateral border. The median portion is divided into two anterior **Proto-gastric** regions (*Pg.*), a median anterior **Mesogastric** region (*Mg.*), a pair of posterior **Metagastric** regions (*Mtg.*), and a median posterior **Urogastric** region

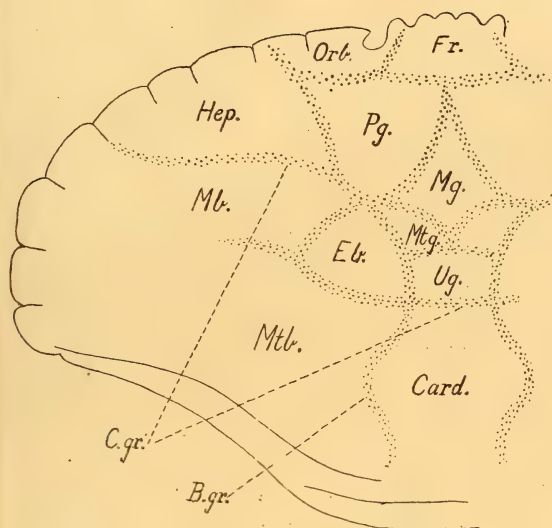


FIG. 2.—Areas of the Carapace.

<i>Fr.</i> = Frontal region.	<i>Mb.</i> = Mesobranchial region.
<i>Orb.</i> = Orbital "	<i>Mtb.</i> = Metabranchial "
<i>Hep.</i> = Hepatic "	<i>Eb.</i> = Epibranchial "
<i>Pg.</i> = Proto-gastric "	<i>Card.</i> = Cardiac "
<i>Mg.</i> = Mesogastric "	<i>C.gr.</i> = Cervical groove.
<i>Mtg.</i> = Metagastric "	<i>B.gr.</i> = Branchio cardiac groove.
<i>Ug.</i> = Urogastric "	

(*Ug.*). The lateral portions are known as the **Hepatic** regions (*Hep.*). Each extends outwards to the antero-lateral border and is bounded behind by the outer part of the cervical groove.

The Thoracic portion comprises that part of the carapace which lies behind the cervical groove. It is

divided by two longitudinal grooves—the *Branchio-cardiac grooves* (*B.gr.*)—into a median **Cardiac** region (*Card.*) and two lateral branchial regions. Each branchial region is made up of an anterior **Mesobranchial** region (*Mb.*) and a posterior **Metabbranchial** region (*Mtb.*) and a small inner **Epibranchial** region (*Eb.*).

The ventral inflected portion of the carapace is divided into two parts by a well defined groove, which may be termed the *pleural groove*, as it probably marks the separation between the cephalo-thoracic terga and pleura. It is along this groove that the carapace splits during ecdysis (see section on Ecdysis). The pleural groove commences at the epistoma and passes outwards and slightly backwards until it almost reaches the posterior end of the seventh lobe of the antero-lateral border. Here it turns backward and runs parallel to the postero-lateral ridge, finally reaching the posterior border with which it becomes continuous. Thus the pleural groove divides the inflected portion of the carapace into an outer, or **Sub-hepatic** region, and an inner, or **Sub-branchial** region. The sub-hepatic region may be considered as an inflected portion of the tergum, and the sub-branchial as belonging to the pleural region. Milne-Edwards regarded the sub-branchial region as part of the cephalo-thoracic epimera, but the inner walls of the branchial chambers undoubtedly represent the epimera.

## 2. Pre-oral Cephalo-thoracic Sterna.

(Pl. III, figs. 19, 20.)

Ventrally the median lobe of the rostrum passes backwards as a triangular plate, the apex of which points posteriorly. This plate, which is separated at its posterior end from the first sternum [antennulary sternum] (*S*<sup>1</sup>)



by a well-defined suture, forms a septum\* between the articular cavities of the two optic peduncles.

From the dorsal side of the sternal region the septum between the above-mentioned articular cavities is short and broad. On a level with the posterior end of these cavities there is a well-marked suture separating the septum from the first sternum.

Immediately in front of the dorsal side of the ophthalmic articular cavities (*o.m.c.*) are two short calcareous plates near the median line, which stretch across to the roof of the carapace. These are the *Procephalic processes* (*p.c.p.*) to which are attached the anterior gastric muscles.

**The First Sternum** ( $S^1$ ) lies in the segment of the first antennae (*ant<sup>le</sup>*.) and separates the articular cavities of these appendages. Owing to the depth of the sternum in this region its relationship to the articular cavities is best seen from the dorsal side of the sternum.

It consists of a median piece lying between the articular cavities of the antennules, and of two lateral expansions which form the posterior boundaries of the articular cavities. Viewed laterally the sternum is seen to have a comparatively great depth. About half way down the anterior face of the sternum is a concavity into which fits a process from the septum between the ophthalmic articular cavities.

From the ventral side the first sternum bounds the posterior and inner sides of the sockets of the antennules, and the lateral prolongations extend as far as the bases of the second antennae.

\*In the present Memoir the optic peduncles are not regarded as modified appendages, and I shall not regard the region of the body from which the eyes arise as the first segment, nor shall I speak of the septum between the articular cavities of the optic peduncles as the first sternum.

Huxley\* in his short account of the crab states that the ophthalmic and antennular sterna are fused, and that the suture is between the fused sterna and the rostrum. I am of the opinion that the whole of the sternum behind the suture belongs to the antennular somite alone, and that the septum separating the articular cavities of the optic peduncles is a posterior prolongation of the rostrum, as described above. An examination of the sternum from the dorsal side (Pl. III, fig. 19) shows that the suture is on a level with the posterior boundary of the ophthalmic articular cavity; so that, if Huxley's view be accepted, we have the ophthalmic sternum entirely behind the articular cavity of its own somite! It is much more reasonable to conclude that the suture separates the ophthalmic septum from the antennular sternum.

The **Epistoma** is a broad plate in front of the mouth and immediately behind the first sternum. It represents the united sterna of the second (antennary) ( $S^2$ ) and third (mandibular) ( $S^3$ ) somites. Its anterior border is concave in front. The two lateral borders gradually slope inwards towards their posterior ends. The posterior border is deeply concave behind and bounds the front edge of the mouth.

The middle part of the anterior border touches the posterior edge of the first sternum and the two outer portions bound the posterior edge of the second antenna. The lateral borders are in contact with the membranous roof of the pre-branchial chamber.

From the middle of the anterior border of the ventral side of the epistoma a median groove passes backwards but does not extend as far as the posterior border. From

\* T. H. Huxley, *Manual of the Anatomy of Invertebrated Animals*, 1877, pp. 340-345.

the posterior edge of this groove a slight depression passes outwards at each side parallel to the anterior border. This depression probably marks the boundary between the antennary and mandibular sterna. This groove is better defined on the dorsal side of the epistoma.

The **Labrum** (Pl. III, fig. 20, *lab.*) is a soft fleshy lobe attached to the middle region of the posterior border of the epistoma. It is surrounded near the middle by a calcareous ring which gives off a median posterior prolongation. At each side of this median plate is a soft fold.

### 3. Post-oral Cephalo-thoracic Sterna (Pl. I, figs. 2, 3, Text fig. 3).

These are all fused together as a single oval-shaped plate situated between the bases of the paired post-oral cephalothoracic appendages. Transverse grooves are present which mark the division of this region into segments or somites, and which mark the places at which the sterna grow inwards to form the endosternites of the endophragmal system.

The surface of the fused sterna is concave laterally in order to accommodate the abdomen, which is always in a flexed condition. This concavity is especially well marked in the males. The surface of the sterna is, however, convex antero-posteriorly.

On the sternum of fifth thoracic somite are two small tubercles (*P.*) which fit into two concavities on the abdomen and thus form an effective locking apparatus which keeps the abdomen in position. These are especially large in the males.

The sternum of the sixth thoracic somite of the female bears a pair of large openings which are the external genital openings.

The sterna of the last four thoracic somites are characterised by a median groove which marks the place at which the "Median plate" of the endophragmal system has grown inwards. The anterior end of this median groove is marked by a very deep depression which is situated at the posterior end of the fourth thoracic sternum.

At the outer and posterior corners of each sternum are backwardly directed areas—the "episterna"

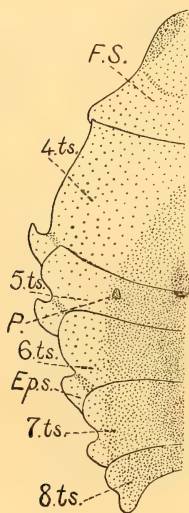


FIG. 3.—Ventral view of post-oral cephalothoracic sterna (male).

*F.S.* = Fused sterna of the two post-oral cephalic and the first three thoracic somites. *4.ts.*—*8.ts.* = Sterna of the 4th to 8th thoracic somites. *Ep.s.* = Episternum. *P.* = Sternal papilla of the abdominal locking apparatus.

(*Eps.*) which run for a short distance alongside the following sternum, from which they are separated by distinct sutures. Between each episternum and the corresponding sternum is a slight groove which is not very distinct in the edible crab. In *Portunus* and other crabs, however, this groove is much more distinct so as to suggest a complete separation between the sternum and episternum. This probably explains why Brooks\* states

\* Brooks, *Handbook of Invertebrate Zoology*.



that the episternum is *anterior* to the outer end of its own sternum. He has evidently mistaken the groove mentioned above for a true suture, and has therefore concluded that the episternum belongs to the following sternum. The last thoracic sternum has no episterna.

At the anterior end of each episternum is a small concavity into which fits the ventral hinge of the coxopodite of the appendage of that somite.

The sterna of the last two cephalic and the first four thoracic somites (*F.S.*) are fused together, without any sign of separation into distinct segments as in the posterior region of the thorax.† There is, however, a slight evidence of a division in front of the fourth sternum of the thorax.

That portion of the thoracic sterna which is covered by the abdomen is characterised by the absence of setae. There are long setae along the outer edges of the episterna, and also on that portion of the fused sterna belonging to the two last cephalic segments and the first four thoracic segments.

In the case of the fourth thoracic sternum the outer edges of the sterna are turned up vertically.

The first post-oral cephalic sternum has two lateral processes which project forwards and give support to the **Metastoma**. The metastoma is a fleshy lobe forming the posterior lip of the mouth.

#### 4. Cephalic epimera.

In the first two cephalic somites it is difficult to identify the epimera, but the latter are probably represented by the region between the outer portion of the articular cavities of these somites and the carapace.

† The two post-oral cephalic sterna, which are represented by two narrow bars at the extreme anterior end of the fused post-oral sterna, are separated from each other, however, by transverse sutures.

The epimera of the third (mandibular) and the two last cephalic somites (maxillary) are probably represented by the membranous roof of the pre-branchial chamber at each side (Pl. III, fig. 18, *r.br.*). This is continuous behind with the thoracic epimera.

### 5. Thoracic epimera

(Plate III, fig. 18, *epm.* 6-12).

The thoracic epimera are represented by a continuous plate at each side forming the inner wall of the branchial chamber. This is the "flanc" of Milne-Edwards. The lower border of the epimera commences immediately above the base of the thoracic appendages. They pass upwards and inwards and are continuous above with the membranous roof of the branchial chamber. At the posterior end they extend upwards almost to the carapace, from which they are only separated by short muscles which pass from the summit of the epimera to the carapace. At the anterior end the epimera are much shallower and become continuous with the roof of the branchial chamber some distance below the carapace.

The fused thoracic epimera form an extremely convex wall which is divided up into segments by vertical sutures, which correspond to the lines of separation between the various somites of the thorax. In this way the epimera are divided up into seven portions. The epimera of the first and second thoracic somites are completely fused, and there is no groove separating them, but apart from this there is one segment of the fused epimera for each of the remaining thoracic somites. The epimeron of the fourth somite is particularly broad. That of the last thoracic somite is not bounded posteriorly by

a groove, but is continuous with the sternum of the same segment.

In their natural position the gills lie upon the thoracic epimera.

### THE ABDOMEN.

The abdomen is continuous with the posterior part of the cephalothorax. The connection is effected by means of an arthrodial membrane, which allows of considerable movement between the two regions. The abdomen is small and in its natural position is closely applied to the sternal region of the thorax. This region differs in the two sexes, being much broader in the female than in the male. This character provides a useful and ready method of distinguishing between the two sexes. There are other differences which require a more detailed examination.

### F e m a l e .

(Pl. I, fig. 2, Pl. IV, fig. 32, Pl. V, fig. 34.)

This consists of six somites and the telson, all of which are freely movable. When lying in position it extends as far forward as the posterior end of the sternum of the third thoracic somite. The locking arrangement for keeping the abdomen closely applied to the thoracic sternum is not so well developed as in the male. It consists of two extremely small tubercles on the fifth thoracic sternum which fit into two slight depressions at the postero-lateral corners of the ventral side of the sixth abdominal somite. The total length of the abdomen is  $2\frac{1}{2}$  times as much as its greatest width.

There are four pairs of appendages, one pair being borne on the second and on each of the three following somites, respectively.

On the dorsal side of the abdomen the terga are separated from the pleura by two longitudinal grooves. Ventrally the median portion is covered by a thin uncalcified cuticle and the outline of the hind-gut is clearly seen.

The hind-gut opens on the ventral side of the telson at the *anus*.

Only the first somite requires any special comment. The upper side of this somite is prolonged forward as a thin triangular flap, the apex of which points anteriorly. This triangular portion is covered by the carapace, only a narrow region at the posterior end of the somite being exposed. All around the anterior edge of this somite is a thin membrane which is continuous with the posterior region of the cephalothorax.

The first two somites are hollowed out laterally to provide free movement for the last pair of thoracic legs.

#### Male (Pl. I, fig. 3).

When lying in position the abdomen extends slightly in front of the middle of the fourth thoracic sternum. It is slightly shorter than the female abdomen and much narrower. As in the latter, the sides of the first two somites (and also part of the third) are hollowed out and pass round the inner sides of the last pair of thoracic appendages.

The first somite has the same arrangement as in the female. The anterior part of the dorsal side is triangular and is covered by the carapace.

The third, fourth and fifth somites are fused together so that there is absolutely no movement between them. The sutures marking their separation still persist.

There are only two pairs of appendages which are present on the first and second somites respectively.



These appendages are peculiarly modified to act as copulatory organs (see sections on Appendages and Reproductive System).

The male abdomen is much more closely applied to the thorax than is the case in the female. This is partly due to the small number of appendages and also to the very effective locking apparatus. The latter is similar to that described in the female and the position of the parts is the same, but the tubercles on the thoracic sternum are much larger, as is also the case with the concavities on the sixth abdominal somite.

Below are given the measurements of the abdomen of a male and female, both having a carapace breadth of 23.5 cm.

No. of Somite.	FEMALE.		MALE.	
	Greatest length.	Greatest width.	Greatest length.	Greatest width.
	mm.	mm.	mm.	mm.
1	17	25	17	22
2	8	22	8	17
3	7	30	7	23
4	8	32	8	20
5	10	35	9	17
6	20	35	13	16
Telson	18	21	13	13
Total length, 88 mm.			Total length, 75 mm.	

### External apertures.

The external openings are as follows:—

The **Mouth**—a median aperture on the ventral side of the cephalic region between the mandibles.

The **Anus**—a median aperture on the ventral side of the telson.

The **Excretory Openings**—one pair. These are situated at the base of the second antennae on the ventral side. Each is covered by an operculum.

The **Female Reproductive Openings**—one pair. These are two large apertures on the sternum of the sixth thoracic somite.

The **Male Reproductive Openings**—one pair. These are situated on the ventral side of the coxopodites of the last pair of thoracic appendages.

#### APPENDAGES (Plate II).

There are five pairs of appendages on the head and eight pairs on the thorax. There are four pairs of abdominal appendages in the female and only two pairs in the male. The appendages are as follows:—

Cephalon.	Somite	I.—1st Antennae (Antennules).	
	„	II.—2nd Antennae.	
	„	III.—Mandibles.	
	„	IV.—1st Maxillae.	
	„	V.—2nd Maxillae.	
Thorax.	Somite	VI.—1st Maxillipedes.	
	„	VII.—2nd Maxillipedes.	
	„	VIII.—3rd Maxillipedes.	
	„	IX.—1st Pereiopods.	
	„	X.—2nd Pereiopods.	
	„	XI.—3rd Pereiopods.	
	„	XII.—4th Pereiopods.	
	„	XIII.—5th Pereiopods.	
		<i>Female.</i>	<i>Male.</i>
Abdomen.	Somite	XIV.—Absent.	1st Pleopods.
	„	XV.—1st Pleopods.	2nd Pleopods.
	„	XVI.—2nd Pleopods.	Absent.
	„	XVII.—3rd Pleopods.	Absent.
	„	XVIII.—4th Pleopods.	Absent.
	„	XIX.—Absent.	Absent.

**The First Antenna or Antennule** (Pl. II, fig. 4, Pl. III, fig. 20) is situated in a deep depression on the ventral side of the cephalic sternum (*s.a.*<sup>1</sup>). This depression or socket is bounded in front by the rostrum (*rost.*), and behind by the lateral expansion of the first sternum (*S*<sup>1</sup>). The outer boundary is formed by the inner edge of the second antenna (*ant.*), and the inner boundary by the median portion of the first sternum. The appendage consists of a broad basal joint, from which is given off on its inner side a two-jointed portion. These three pieces together form the *protopodite* (*prot.*). From the end of the distal segment of the protopodite arise two many-jointed flagella—an inner *endopodite* (*end.*) and an outer *exopodite* (*ex.*). The exopodite is the larger of the two, and bears on its inner side a tuft of long setae. The “olfactory” setae are small setae on the ventral side of the exopodite (see section on Sense Organs).

On the dorsal side of the basal segment of the protopodite is a longitudinal groove covered with long setae. This groove marks the place where the auditory sac opens to the exterior in the young animal. In the adult crab this groove is completely closed, although it remains open a short time after ecdysis.

In their natural position the three parts of the protopodite are folded on one another. The second segment is closely applied to the inner side of the basal segment. The third segment is bent back along the dorsal side of the second, and its distal end lies in an excavation made for its reception in the dorsal wall of the basal segment.

**Second Antenna** (Pl. II, fig. 5, Pl. III, fig. 20). This consists of a large basal portion (*prot.*) which is fused to the carapace, and a distal flagellum, which consists of two long basal segments and a number of short rings,

arising from the anterior and inner region of the basal portion. At the posterior and outer corner of the large basal segment is the operculum (*op.*), which covers the external excretory opening. This operculum probably represents the *coxopodite* and the larger basal portion the *basipodite*, the two together forming the *protopodite*. The flagellum probably represents the *endopodite*.

The outer edge of the basipodite is fused to the sub-hepatic region of the carapace. Backward processes from the supraciliary (*S.L.*) and supra-orbital lobes fuse with the anterior end of the basipodite. The inner and posterior corner of this segment is in contact with the lateral portion of the first sternum, and the posterior border of the same segment is in contact with the epistoma.

**The Mandible** (Pl. II, fig. 6) lies at the side of the mouth. The main portion is an elongated strongly calcified structure which is divided into two parts—an inner part, which projects over the ventral region of the mouth, and acts as the “jaw,” and an outer part, the *apophysis* (*apoph.*), to which are attached the tendons of the mandibular muscles. At the outer extremity is the tendon of the external adductor (*t.ex.ad.*). Behind this, attached to a small projection, is the tendon of the external abductor (*t.ex.ab.*). To the posterior and inner side of the apophysis is attached the tendon of the internal adductor (*t.int.ad.*). The internal abductor arises from the apophysis on the inner side of the base of the tendon of the external adductor. There is no tendon for the internal abductor. Anteriorly the mandibular palp (*md. palp.*) arises from the inner side of the apophysis. The mandible is hinged to the epistoma by means of a small projection below the palp. There is no definite hinge posteriorly, but the posterior border of the inner region



of the apophysis is attached to the metastoma by means of a somewhat flexible membrane.

**The First Maxilla** (Pl. II, fig. 7, Pl. IV, fig. 26), which arises immediately behind the mandible, is small and is made up of a *protopodite* and *endopodite*. The exopodite is absent. The protopodite is on the inner side and is composed of two distinct pieces—a narrow proximal *coxopodite* (*C.*) and a larger *basipodite* (*B.*) which is external to the coxopodite. The *endopodite* (*end.*) arises from the outer side of the basipodite, and consists of a broad proximal leaf-like region and a narrower distal region. From the distal extremity of both parts of the protopodite arise fairly strong setae.

**The Second Maxilla** (Pl. II, fig. 8, Pl. IV, fig. 27) consists of an inner *protopodite*, a median *endopodite* (*end.*) and an outer *exopodite* (*Scaph.*). The protopodite is composed of a *coxopodite* (*C.*) and a *basipodite* (*B.*), each of which is bilobed. The two lobes of the coxopodite are long and slender, and are clearly separated from one another. Those of the basipodite are broader, and the separation between the two lobes is only partial. On the outer side of the basipodite is the small endopodite, which ends in a long narrow process. On the outer side of the endopodite and arising from the basipodite, is the large modified exopodite which is known as the *scaphognathite* (*Scaph.*). This is a broad plate of irregular shape which lies in the pre-branchial chamber. By means of its rapid and complicated movement it bales the water out of the branchial chamber.

In the **First Maxillipede** (Pl. II, fig. 9) the protopodite is on the inner side. The *coxopodite* (*C.*) is small and richly clothed with setae, and the *basipodite* (*B.*) is a long lamella having two rows of setae on its outer edge. The *endopodite* (*end.*) is between the exopodite and the proto-

podite. It is membranous, the proximal half being flattened laterally and the distal half dorso-ventrally. The *exopodite* (*ex.*) is long and slender and consists of a long proximal segment, which is as long as the endopodite, and a distal many-jointed flagellum (*flag.*) which in its natural position projects inwards at right angles to the proximal segment. During life this flagellum is exceedingly active. From the outer side of the protopodite arises the long *flabellum* (*flab.*) (or epipodite). This is a long narrow membranous plate which passes back into the branchial chamber above the gills. The proximal portion of the flabellum is broad and leaf-like.

The **Second Maxillipede** (Pl. II, fig. 10) has the exopodite and flabellum in the same position as in the previous appendage. The flabellum (*flab.*), however, is much shorter than that of the first maxillipede, and lies along the upper portion of the thoracic epimera and below the gills. The protopodite is much reduced, but the proximal *coxopodite*\* (*C.*) and the distal *basipodite* (*B.*) can still be made out. The endopodite is comparatively larger than the same part in the first maxillipede. It arises from the basipodite and is divided into five movable segments. The first or proximal segment—the *ischiopodite* (*I.*) is small. The second segment or *meropodite* (*M.*) is the longest, and equal in length to the other four segments. The three distal segments are small, and between the second and third segment the endopodite turns inwards, the distal segments being at right angles to the meropodite. The names of the third, fourth and fifth segments are *carpopodite* (*C.*<sup>1</sup>), *propo-*

\* The following abbreviations are sometimes used:—*coxa* = coxopodite; *basis* = basipodite; *ischium* = ischiopodite; *meros* = meropodite; *carpos* = carpopodite; *propus* = propodite; *dactylos* = dactylopodite.

*dite* (*P.*) and *dactylopodite* (*D.*) respectively. Arising from the appendage immediately in front of the base of the flabellum is a *podobranch* (*pod. br.*) (see section on Respiratory Organs).

The **Third Maxillipede** (Pl. II, fig. 11, Pl. IV, fig. 30) is built on a similar plan to the previous appendage. The basis and the ischium are fused together to form the *basi-ischium* (*B.-I.*). The *podobranch* (*pod. br.*) is very small and arises from the coxopodite. The flabellum (*flab.*) lies on the lower part of the thoracic epimera below the gills. The endopodite and exopodite (*ex.*) are closely applied together and are much flattened so as to form with the same appendage of the other side an effective operculum closing over the remaining mouth parts, and preventing the exhalent current of water from the branchial chamber from passing out except in front of the scaphognathite.

The mandibles, maxillae and maxillipedes all lie around the mouth in the large depression between the anterior parts of the sub-branchial regions of the carapace. The ventral side of the third maxillipedes is on a level with the sub-branchial region. As the flabellum of this appendage passes back into the branchial cavity, it passes along the front of the anterior inhalent branchial aperture, and reduces the size of the aperture considerably. At this point the flabellum\* is also richly clothed with strong setae, which probably act as a "strainer" in conjunction with the setae present on the front part of the coxa of the chela (see section on Respiratory Organs).

The **First Pereiopod** (or chela) (Pl. II, fig. 12, Pl. III,

\* The coxopodite of the third maxillipede is prolonged outwards, and bounds the inner part of the inhalent aperture. The flabellum bounds the outer part. Both are richly clothed with setae on their posterior faces.

fig. 21) is the largest appendage in the body. It consists of seven segments (or podomeres). A comparison with the third maxillipede indicates that the two proximal segments belong to the protopodite, and the remaining five to the endopodite. There is no exopodite present. The seven segments have the same names as the similar parts in the third maxillipede. With the exception of the second and third segments, which are fused together to form the *basi-ischium* (*B-I.*), all the parts are freely movable. The *basi-ischium* has a thin groove running around it, which marks the separation of this fused portion into its two constituent parts. This groove is known as the *fracture plane* because it is at this point that the animal fractures the limb during the process of self-amputation (see section on Autotomy). The two distal segments of the limb are slightly modified to form the pincer which constitutes an effective prehensile organ.

Each of the movable segments swings in a different plane, so that the combined movement of the whole appendage is a very complete one. The coxopodite (*C.*) articulates with the body by means of two hinges, one being dorsal (Pl. III., fig. 21, *d.*) and the other ventral (*v.*). The dorsal hinge is attached to the antero-ventral corner of the epimeron of the fourth thoracic somite, and the ventral hinge articulates at the postero-lateral corner of the sternum of the same segment. Thus the motion of the coxopodite is in a horizontal plane, moving backward and forward. The fused *basi-ischium* (*B.-I.*) articulates with the coxa by an antero-dorsal ( $d^1$ ) and a postero-ventral hinge ( $v^1$ ), and the movement is upwards and downwards in a plane making an angle of about  $45^\circ$  with the vertical. The meros (*M.*) has very little movement. Its two hinges are antero-dorsal ( $d^2$ ) and postero-ventral respectively ( $v^2$ ), and the small degree of movement of



which this segment is capable is almost in a vertical plane. The two hinges of the carpos ( $C^1$ ) are situated dorsally ( $d^3$ ) and ventrally ( $v^3$ ), and the segment moves forward and downward. The propodite ( $P.$ ) has two hinges—dorsal ( $d^4$ ) and ventral ( $v^4$ ). The former is external to the latter, and the segment moves forward and slightly upward. In the dactylos ( $D.$ ) the hinges are horizontal and the segment swings in a vertical plane.

The dimensions of the various segments of the chela in a female crab (carapace breadth 23.5 cm.) are as follows:—

	Anterior length.	Posterior length.
Coxopodite ...	7 mm.	11 mm.
Basi-ischiopodite ...	17 „	6 „
Meropodite ...	19 „	32 „
Carpopodite ...	10 „	30 „
Propodite ...	50 „	20 „
Dactylopodite ...	20 „	30 „

The dorsal sides of the basi-ischium and of the meros are flattened so that they can be closely applied to the anterior portion of the sub-branchial and sub-hepatic regions of the carapace, and in these places setae are absent from the carapace.

Between the meros and the carpos the limb is capable of bending on itself, so that the anterior borders of the propodite and the carpos become closely applied to the anterior borders of the basi-ischium and the meros.

On the dorsal side of the basi-ischium and meros there are irregular grooves. These are the lines of absorption (Pl. II, fig. 12, *abs.*) (see section on Ecdysis).

**Pereiopods 2-5** (Pl. II, fig. 13). These are known as the “walking legs.” Their essential structure is the same as that of the chela. The one obvious difference is that in all the walking legs the propodite has not an

outgrowth which, in conjunction with the dactylos, forms a pincer. In other words, the walking legs terminate in a single claw, and are not chelate.

The three terminal segments are capable of being flexed upon the proximal segments. This flexion is in a vertical plane.

**Pleopods** (Female) (Pl. II, fig. 17). There are four pairs of appendages on the female abdomen, one pair being situated on each of the second, third, fourth and fifth somites respectively. They are all similar in structure. Each pleopod is attached to the abdomen by a basal piece—the *protopodite* (*prot.*). From this arise two long pieces—an outer *exopodite* (*ex.*) and an inner *endopodite* (*end.*). The exopodite is almost cylindrical in section, and about half as long as the abdomen.

From the outer and inner edges of the exopodite rows of setae arise. Each seta has short fine branches given off from each side of the central stem. The endopodite is about as long as the exopodite. About one-third of its length from the base is a well-defined transverse groove. The setae are arranged, as in the exopodite, along the outer and inner edges, but they arise in small bundles. The setae are very long and do not bear offshoots except near the tip, where there are a few very fine short branches. The eggs are attached to the endopoditic setae.

**Pleopods** (Male) (Pl. II, figs. 14, 15, 16). There are two pairs of abdominal appendages in the male, which are situated on the first two somites. Both pairs are greatly modified and act as copulatory organs (see section on Reproductive Organs).

*First pair* (Pl. II, fig. 14). Each consists of two parts—a broad basal portion, probably the *protopodite* (*prot.*), and an elongated distal portion, which is rolled

on itself longitudinally to form a tube. This distal portion probably represents the endopodite (*end.*). The two basal portions fuse in the middle line, thus forming a tunnel-like structure extending backward below the second somite. Below the fused basal portions of the first pleopods arise the *second pair* of appendages (Pl. II, fig. 15). Each consists of two parts—a horizontal rod (*prot.*) projecting posteriorly, and a vertical rod (*end.*) attached to the posterior end of the first portion. The vertical rod is divided into two parts by a transverse groove. The horizontal rod probably represents the protopodite, and the vertical portion is the endopodite. There is no trace of an exopodite on any of the male pleopods.

The vertical rod-like portion of the second pleopod fits into the tube of the first pleopod.

### ENDOPHRAGMAL SKELETON

(Pl. III, fig. 18, Text figs. 4, 5, 6, 7).

The post-oral region of the cephalothorax has an extremely complex system of internal plates, known as the *e n d o p h r a g m a l s k e l e t o n*. Essentially this system may be said to consist of a number of inwardly-projecting plates arranged transversely so as to divide up the interior of the cephalothorax into a series of irregular compartments. Each partition, or *a r t h r o p h r a g m*, arises at the junction of two somites, and is formed by an infolding of the sternal and epimeral exoskeleton between these somites. Thus, each plate of the endophragmal skeleton is double, and is composed of two flattened plates of exoskeleton which are closely applied together.

The primary function of the endophragmal system is

to afford attachment for the muscles of the proximal region of the appendages in this region of the body. It is also useful in supporting and protecting certain portions of the viscera.

Although at first sight the arthrophragms of the first five post-oral cephalothoracic somites differ in a marked degree from those of the posterior thoracic region, it will be shown that all are built on the same plan.

#### DESCRIPTION OF A TYPICAL ARTHROPHRAGM

(Text fig. 4).

The fourth thoracic arthrophragm (between the fourth and fifth thoracic somites) may be taken as a type. It is a vertical partition extending inwards at each side from the line of junction of the fourth and fifth thoracic epimera. The portion of the partition in contact with the thoracic sternum arises between the fourth and fifth thoracic sterna. Thus we may distinguish between two kinds of plates, viz., those growing inwards from the epimera—the **endopleurites** (Pl. III, fig. 18, *ep.*, also Text figs. 4, 5, 7), and those arising from the inner side of the sternum—the **endosternites**. Each arthrophragm consists, therefore, of an outer endopleurite and an inner endosternite at each side of the middle line. The two endosternites in the arthrophragm under discussion are separated from each other in the middle line by the *median plate* (fig. 18, *med. p.*), which is an ingrowth from the median suture present on the last four thoracic sterna. The plates of which the arthrophragm is composed are sometimes known as the “apodemata.”

The **Endosternite** is irregular in shape and has five principal borders.

The *median border* is vertical, and is the part of the endosternite in contact with the median plate.



The *sternal border* (Text fig. 4, *Sb. s.*) is in contact with the sternum, and forms the ventral boundary of the endosternite.

The *articular border* (*Ab. s.*) passes upwards and outwards, and is equal in length to the sternal border. It is connected with the arthrodial membrane in contact with the coxopodites of the fourth and fifth thoracic appendages.

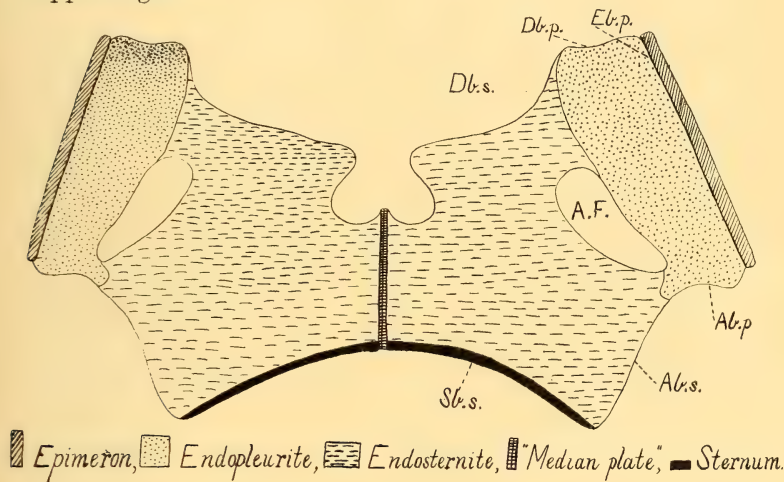


FIG. 4.—Diagram of a typical arthropod.

- Db.p.* = dorsal border of the endopleurite.
- Db.s.* = dorsal border of the endosternite.
- Eb.p.* = epimeral border of the endopleurite.
- Ab.p.* = articular border of the endopleurite.
- Ab.s.* = articular border of the endosternite.
- Sb.s.* = sternal border of the endosternite.
- A.F.* = apodemal foramen.

The *outer border* passes inwards and upwards, and at its upper and lower ends fuses with the endopleurite. This fusion is interrupted in the middle region of the border by the large *apodemal foramen* (*A.F.*) which lies between the endosternite and endopleurite.

The inner part of the *dorsal border* (*Db. s.*) passes

upwards and outwards from the median line, describing almost a semi-circle. The upper edge of the semi-circle almost reaches the median line. Thus the inner portion of the dorsal border of each side surrounds an almost closed cavity, which corresponds to the "sternal canal" of the *Macrura*.

The *Endopleurite* is rectangular in shape, and its length is about twice as great as its width. Four borders may be distinguished.

The *inner border* is in contact with the outer border of the endosternite at its upper and lower ends. In the intermediate region it forms the outer boundary of the apodemal foramen.

The *articular border* (*Ab. p.*) is in contact with the upper part of the arthrodial membrane connecting the coxopodites of the fourth and fifth thoracic appendages.

The *epimeral border* (*Eb. p.*) is in contact with the fourth and fifth thoracic epimera.

The *dorsal border* (*Db. p.*) bounds the dorsal free end of the endopleurite.

Above the apodemal foramen the endopleurite becomes fused on its posterior face with the following arthrophragm, and the anterior face of the arthrophragm under discussion becomes fused with the preceding endopleurite.

All the arthrophragms of the post-oral cephalo-thoracic region are built on the above plan, that is to say, each somite has one endosternite and one endopleurite at each side. But in some cases the homology is very much disguised.

The last five thoracic arthrophragms are very similar to the one described, but the anterior arthrophragms are extremely reduced. It is, therefore, advisable to describe the endophragmal skeleton in two parts.

(1) The last five thoracic arthrophragms, beginning in front and working backward (posterior thoracic).

(2) The two post-oral cephalic arthrophragms and the first three thoracic arthrophragms, beginning behind and working forward (anterior post-oral).

#### (1) POSTERIOR THORACIC ENDOPHRAGMAL SYSTEM

(Pl. III, fig. 18, and text, fig. 5).

This consists of the arthrophragms of the last five thoracic somites.

The *median plate* commences at the posterior end of the fourth thoracic sternum. At first it is extremely shallow, but as it proceeds posteriorly it increases in height. It is present in the last four thoracic somites.

As in other parts of the endophragmal system, the median plate is composed of two closely applied portions of the exoskeleton. In the fifth thoracic somite these two parts remain separate, and the cavity between them opens to the exterior at the posterior end of the fourth thoracic sternum.

Each endosternite is at right angles to that part of the sternum from which it arises, and similarly each endopleurite arises at right angles to the epimeron. If the sternum were horizontal throughout its entire length, and also if the epimeral wall at each side were vertical, the endophragmal system would be represented by a series of vertical partitions arranged one behind the other. This is the case in the *Macrura*. In the *Brachyura*, however, neither the sterna nor epimera follow this arrangement. The thoracic sternum is extremely convex antero-posteriorly and has an extreme upward tilt at its posterior end. The epimeral wall, instead of having a flat surface, is extremely convex on its outer face. The shape of the sternum and of the epimeral wall gives rise to much

complexity in the endophragmal system of the last five thoracic somites. The endosternite and the endopleurite of the same arthrophragm instead of being in the same plane, as in the *Macrura*, may be situated at a considerable angle to each other, so that it is difficult to believe that they belong to the same segment. The fifth endosternite is almost vertical, but the succeeding endosternites incline more and more forward until the last arthrophragm is practically horizontal.

The endopleurites of each arthrophragm become fused with the anterior face of the following arthrophragm, and thus we have each somite divided into four chambers. There is an outer chamber at each side lying between two consecutive endopleurites, and bounded on the outer side by the epimeron and on the inner side by the backward growth of the endopleurite. These chambers may be called the *Pleural muscle chambers* (Text fig. 6, *P.*).

There is also an inner chamber at each side, lying between two consecutive endosternites, and separated from one another by the median plate. We designate these the *Sternal muscle chambers* (Text fig. 6, *S.*).

These pleural and sternal muscle chambers contain the muscles which work the two basal segments of the appendages in this region.

The muscle chamber of the last walking leg is not divided into parts owing to the absence of a separate endopleurite in this somite. Therefore this last muscle chamber may be known as the *Pleuro-Sternal muscle chamber* (Text fig 6, *PS.*). Each of these chambers has an antero-lateral prolongation, which extends forward as far as the posterior face of the fourth thoracic arthrophragm.

The **fourth thoracic arthrophragm** (Text fig. 5, *A.*) arises between the fourth and fifth thoracic somites. This arthrophragm has already been described.



The **fifth thoracic arthrophragm** (Text fig. 5, *B.*) arises between the fifth and sixth thoracic somites. All the parts are very similar to those described in the fourth arthrophragm. The sternal border is slightly more

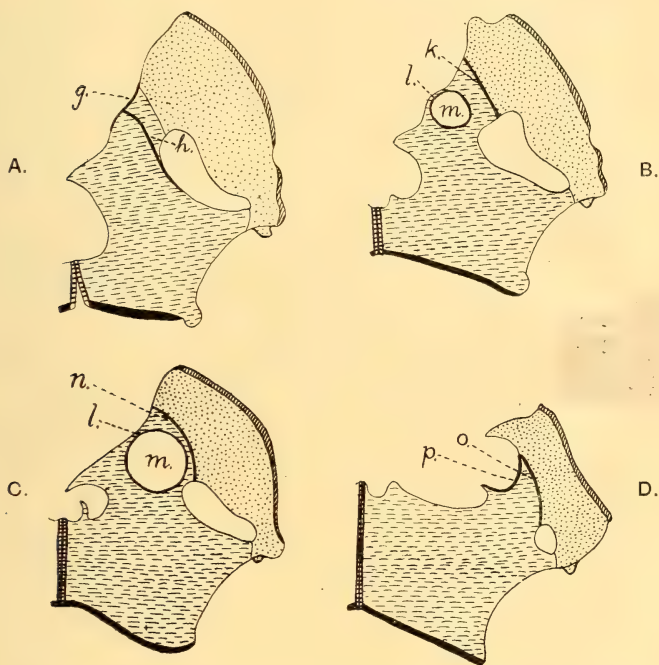


FIG. 5.—Anterior view of the left side of thoracic arthrophragms.

A. = 4th thoracic arthrophragm.

B. = 5th thoracic arthrophragm.

C. = 6th thoracic arthrophragm.

D. = 7th thoracic arthrophragm.

(The parts are shaded as in Fig. 4).

*g.* = line of fusion with the following arthrophragm.

*h.* = line of fusion with the 3rd thoracic endopleurite.

*k.* = line of fusion with the 4th thoracic endopleurite.

*l.* = line of fusion with posterior face of the preceding thoracic endosternite.

*m.* = antero-lateral extension of pleuro-sternal muscle chamber.

*n.* = line of fusion with the 5th thoracic endopleurite.

*o.* = line of fusion with the 6th thoracic endopleurite.

*p.* = line of fusion with the 6th thoracic endosternite.

arched. The apodemal foramen is not quite so large. There is an additional cavity left in the dorsal side of the endosternite at each side (*m.*) This is formed by the

anterior prolongation of the last pleuro-sternal muscle chamber.

The endosternite is almost vertical, but there is a slight forward tilt. The endopleurite is slightly concave on its anterior face, and its plane is slightly posterior to that of the endosternite. The border of the endosternite surrounding the sternal canal has a slight notch. Around the foramen of the pleuro-sternal muscle chamber the endosternite of this arthropod fuses in front with the fourth endosternite (*l.*) and posteriorly with the sixth endosternite. Similarly along the outer border of the endosternite, above the apodemal foramen, this arthropod is fused in front with the fourth endopleurite (*k*) and behind with the sixth endopleurite.

The **sixth thoracic arthropod** (Text fig. 5, *C.*) arises between the sixth and seventh thoracic somites.

The endosternite is convex on its anterior face, and its plane is inclined considerably forward. Its median border is longer than in the previous arthropods. The notch in the sternal canal is much more pronounced than in the fifth arthropod. The upper border of the sternal canal is bent posteriorly, and its inner tip becomes fused with the upper edge of the median plate in the last somite. The dorsal border is fused with the anterior (or dorsal) edge of the last arthropod. In this way the seventh endosternite is completely roofed over and cannot be seen clearly until the sixth endosternite is removed. As in the previous arthropod, there is a large foramen in the dorsal region of the endosternite through which the pleuro-sternal muscle chamber passes (*m.*).

The endopleurite is very similar to that of the fourth arthropod. At the junction of the endosternite and endopleurite this arthropod fuses in front with the fifth endopleurite (*n.*), and behind with the seventh endo-

pleurite. Also at the edge of the foramen bounding the pleuro-sternal muscle chamber this endosternite is fused in front to the fifth and behind to the seventh endosternite (*l.*).

The **seventh thoracic arthrophragm** (Text fig. 5, *D.*) lies between the seventh and eighth thoracic somites.

The endosternite is inclined at an angle of  $50^{\circ}$  to the vertical, the upper border being anterior. It is almost completely covered by the overhanging sixth endosternite. The median border is very deep and the sternal canal is very small. The dorsal border is almost level, and partly bounds the ventral side of the pleuro-sternal muscle chamber. The endosternite does not completely surround this chamber as in the two previous arthrophragms. The sternal border is inclined at a considerable angle to the horizontal. The apodemal foramen is small.

The plane of the endopleurite is almost at right angles to that of the endosternite. At the junction of the endosternite and endopleurite this arthrophragm fuses in front with the sixth endopleurite (*o.*), and where the endosternite borders the pleuro-sternal muscle chamber there is a fusion with the sixth endosternite (*p.*).

The **eighth thoracic arthrophragm** (Pl. III, fig. 18, *e. st.* 13) lies at the posterior end of the last thoracic somite. In this somite there is no separate epimeron. It is probably fused with the sternum. The arthrophragm, therefore, shows no division into endosternite and endopleurite. It may be accepted, however, that this arthrophragm represents the fused endosternite and endopleurite. It consists of two halves, which are separated in the median line by the posterior end of the median plate. This arthrophragm is practically horizontal, and was designated the "sella turcica" by Milne-Edwards. As already stated, the last arthrophragm fuses in front

with the dorsal border of the sixth endosternite. Between this arthrophragm and the seventh endopleurite there is a large foramen.

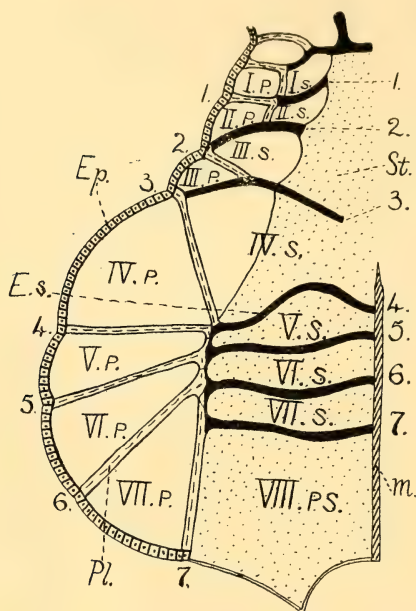


FIG. 6.—Diagrammatic plan of the endophragmal system to show the muscle chambers. (The corresponding parts are shaded similarly throughout).

1—7 = thoracic arthro-phragms 1 to 7.

I.P. — VII.P. = pleural muscle chambers of thoracic somites 1—7.

I.S. — VII.S. = sternal muscle chambers of thoracic somites 1—7.

VIII.P.S. = pleuro-sternal muscle chambers of last thoracic somite.

Ep. = epimeron.

E.s. = endosternite.

Pl. = endopleurite.

St. = sternum.

m. = median plate.

## (2) ANTERIOR POST-ORAL ENDOPHRAGMAL SYSTEM

(Text fig. 7).

This consists of the last three thoracic and the two post-oral cephalic arthrophragms.

The nature of the epimera and sterna in this region naturally decides the form and extent of the corresponding arthrophragms.

The apparently great differences between the endophragmal system of this region and that of the posterior thoracic somites is due to three main causes.



(1) There is no median plate. This only begins at the level of the fourth thoracic arthrophragm.

(2) The post-oral sterna anterior to the fourth thoracic arthrophragm are all fused together. Consequently there can be no broad plate-like endosternites formed as in growths between the somites. The small endosternite present in each somite of this region is rod-like, and represents merely the articular border of the typical endosternite. (The third thoracic endosternite has the form of a fairly broad and deep plate, and is therefore an exception to this rule.)

(3) The epimera in front of the second thoracic arthrophragm are fused together, so that the endopleurite in these somites are extremely reduced and represent only the articular border of the typical endopleurite.

Here, as in the posterior thoracic region, each endopleurite gives off a posterior out-growth, which fuses with the following arthrophragm. So that pleural muscle chambers and sternal muscle chambers may be made out, but owing to the rod-like nature of their constituent parts, they have a very different appearance from the muscle chambers of the posterior somites of the thorax (see Text fig. 6, also Pl. III, fig. 18).

The **third thoracic arthrophragm** (Text fig. 7, *E.*) arises between the third and fourth thoracic somites.

Each endosternite (Pl. III, fig. 18, *e.st.8*) differs from that of the typical arthrophragm described above. It arises merely from the outer edge of the sternum, so that the two endosternites are separated from each other by the entire width of the sternum in this region. The endosternite is a broad and deep plate facing downwards and backwards. The dorsal and inner corner is prolonged inwards and backwards and almost meets the similar part from the other side.

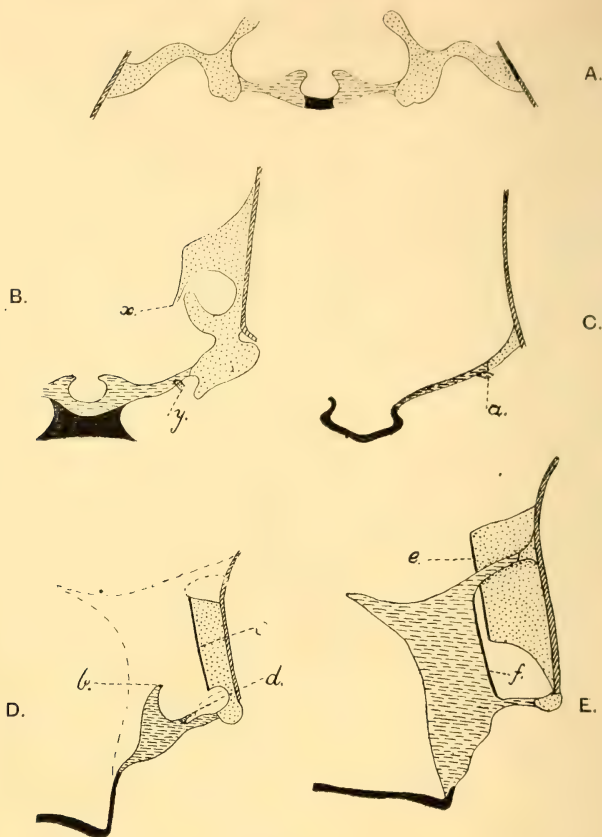


FIG. 7.

- A. = anterior view of 1st post-oral cephalic arthropod.  
 B.—E. = anterior views of the left side of the following arthropod.  
 B. = 2nd post-oral cephalic arthropod.  
 C. = 1st thoracic arthropod.  
 D. = 2nd thoracic arthropod. E. = 3rd thoracic arthropod.  
 (The parts are shaded as in Fig. 4).  
 a. = junction of 2nd cephalic endopleurite with 1st thoracic endosternite.  
 b. = point of fusion between 2nd thoracic endosternite and 2nd cephalic endopleurite.  
 c. = line of fusion between 2nd thoracic endopleurite and 3rd thoracic endosternite.  
 d. = point of fusion with the 1st thoracic endopleurite.  
 e. = line of fusion between 3rd thoracic endopleurite and the 4th thoracic endosternite.  
 f. = line of fusion between 3rd thoracic endosternite and the 2nd thoracic endopleurite.  
 x. = point of fusion between the 2nd cephalic endopleurite and the 2nd thoracic endosternite.  
 y. = point of fusion with 1st cephalic endopleurite.  
 (The dotted line in Fig. D represents the 3rd thoracic endosternite.)

On its anterior face the endosternite is connected with the narrow plate-like second thoracic endopleurite (*f.*). Near the point of junction of these two plates the dorsal and articular borders are prolonged backwards as rod-shaped pieces, each of which comes into contact with anterior rod-like outgrowths from the corresponding borders of the third thoracic endopleurite.

The endopleurite arises between the third and fourth epimera. It gives off two short anterior rod-like prolongations from the dorsal and articular borders which fuse with the rod-like extensions of the endosternite mentioned above. The main part of the endopleurite, however, consists of a broad plate, which passes backwards and fuses with the fourth thoracic arthrophragm (*e.*).

**Second thoracic arthrophragm** (Text fig. 7, *D.*). The endosternite is much more reduced than that of the third thoracic arthrophragm. It arises from the upturned edge of the sternum in this somite, and has a very irregular shape. Its inner portion passes upwards, and fuses with a narrow membranous process projecting downwards from the last cephalic endopleurite (*b.*).

The articular border is prolonged outwards as a rod-like process, which fuses with the extremely small articular border of the endopleurite of the same arthrophragm. About half way along the articular border the endosternite fuses with a posterior rod-like extension of the first thoracic endopleurite (*d.*).

The endopleurite of this arthrophragm is a deep narrow plate arising at the junction of the second and third thoracic epimera. From its lower end it sends forward a short process which fuses with the outer part of the endosternite. The main part of the endopleurite passes backwards and becomes fused with the third thoracic endosternite (*C.*), as described above.

**First thoracic arthrophragm** (Text fig. 7, *C.*). The endosternite arises from the upturned edge of the sternum. It consists of a simple rod which passes backwards, upwards and outwards parallel to the articular border of the second thoracic endosternite. It fuses with the endopleurite of the same arthrophragm, but immediately before doing so it comes into contact, on its anterior side, with a posterior prolongation from the last cephalic endopleurite (*a.*).

The epimera of the first and second thoracic somites are fused together, and the endopleurite of this arthrophragm arises from the ventral edge of the fused epimera immediately in front of the origin of the second thoracic endopleurite. It is rod-like, and passes forwards and inwards in precisely the same plane as the first thoracic endosternite, with which it fuses. Near its fusion with the latter, the endopleurite gives rise to a posterior process which fuses with the second thoracic endosternite.

**Last cephalic arthrophragm** (Text fig. 7, *B.*). The endosternites of the two post-oral cephalic arthrophragms are fused together, but there is a distinct longitudinal suture present, which assists in the identification of the two parts.\* The fused endosternites pass outwards and backwards parallel to the first thoracic endosternite. After a short distance the last cephalic endosternite becomes distinct from the anterior endosternite, and at the point of separation a prolongation from the first cephalic endopleurite fuses with the endosternites (*y.*). From this point the posterior endosternite passes outwards and fuses with the lower border of the last cephalic endopleurite.

The last cephalic endopleurite is an irregular

\* There is also a well-marked groove separating the sternum of these two cephalic somites.



membranous plate divided into a dorsal and a ventral portion. The dorsal portion has on its inner side a downwardly projecting process which fuses with the upper part of the second thoracic endosternite (*x.*) as described above. The ventral portion of the endopleurite has an upper crescent-shaped region and a lower part which fuses with the endosternite.

From the posterior side of the lower portion of the endopleurite is given off a rod-like process which fuses with the first thoracic endosternite.

**First post-oral cephalic arthrophragm** (Text fig. 7, *A.*). In addition to the portion fused with the last cephalic endosternite, the endosternite of the above arthrophragm has an anterior process at each side which form the skeleton of the metastoma (Pl. III, fig. 18, *met.*) or posterior lip of the mouth.

The endopleurite arises from the soft membranous epimeron immediately behind the insertion of the external abductor muscle of the mandible. It passes backwards and gives rise to a small upwardly directed process, and afterwards becomes joined to the fused endosternites.

#### INTEGUMENT (Text fig. 8).

The crab is covered by a continuous chitinous exoskeleton, which serves partly as a protective covering and also as a means of attachment for the muscles. The main portion of this exoskeleton is strongly calcified. Between the movable somites of the abdomen, however, and also between the articulating segments of the appendages, the exoskeleton remains uncalcified in order to allow of free movement, and has the appearance of a thin chitinous membrane, known as the "arthrodial membrane."

The exoskeleton of the ventral region of the abdomen

is but feebly calcified. The outer walls, the floor and roof of the branchial chamber and the roof of the pre-branchial chamber are also extremely thin and membranous. The chitinous linings of the fore-gut and hind-gut, which are continuous with the exoskeleton, are uncalcified, except in those regions of the fore-gut where the ossicles are present. The gills, also, are covered by an extremely fine chitinous layer.

The integument of the crab consists of an epidermis, below which lies the dermis. On the outer side of the epidermis is a chitinous layer, the thickness of which differs considerably in various parts of the body. This outer chitinous layer is a product of the epidermis, and constitutes the exoskeleton already referred to. The chitinous layer may be impregnated with calcareous salts.

The **epidermis** [Chitogenous epithelium, Vitzou\*] (Text fig. 8, *e.*) consists of a single row of columnar cells resting upon a *basement membrane* (*f.*). These cells differ in their appearance in various parts of the body, and also show marked changes during the interval between one act of ecdysis and the next. In the dorsal integument of the hard crab, for example, the cells of the epidermis are only moderately columnar, but in the oesophagus of the same animal the cells are extremely elongated. In the soft crabs the cells are of much greater length comparatively than in the hard crabs.

In some regions where we have two parts of the integument coming close together, such as at the edge of the carapace and also the gill lamellae, the cells of the epidermis sometimes become extremely elongated and pass across the dermis to fuse with similar cells from the

\* Vitzou, A. N. "Recherches sur la structure et la formation des téguments chez les Crustacés Décapodes." *Arch. de Zoologie expér. et gén.*, T. X. [1882], p. 451.

epidermis of the opposite side. Vitzou has termed such cells "colonnades de soutien."

The cells of the epidermis are also elongated at the point where the muscle fibres arise.

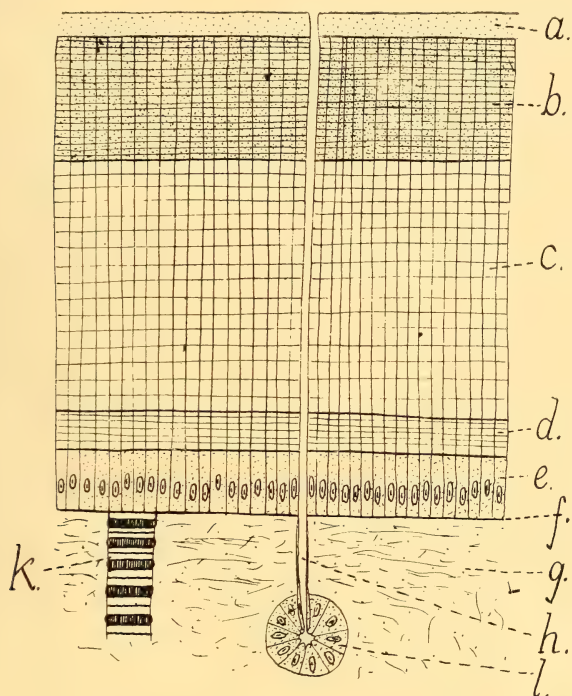


FIG. 8.—Diagrammatic section through the integument of a hard crab.

- |                           |                                   |
|---------------------------|-----------------------------------|
| a. = cuticle.             | f. = basement membrane.           |
| b. = pigmented layer.     | g. = dermis.                      |
| c. = calcified layer.     | h. = duct of the cutaneous gland. |
| d. = non-calcified layer. | k. = muscle attached to the base- |
| e. = epidermis.           | ment membrane.                    |
|                           | l. = cutaneous gland.             |

The **dermis** (*g.*) lies below the basement membrane, and varies in thickness. It consists mainly of a network of connective tissue fibres and scattered cells. There is a layer of pigment cells close to the basement membrane.

As pointed out by Cuénot,\* there are two kinds of cells present in the connective tissue which contain reserve material. These are the "cellules de Leydig" and the "cellules protéiques." The former contain glycogen, and are present in great numbers, especially when the period of ecdysis approaches. The latter are also present in great abundance, and contain proteid material.

The cutaneous glands are also embedded in the dermis. The muscle fibres stretch across the dermis, and are attached to the inner side of the basement membrane. The muscles when dissected appear to be attached to the exoskeleton, but an examination of sections reveals the fact that they do not extend farther than the basement membrane.

The **chitinous layer** of the integument is situated on the outer side of the epidermis, and consists of several layers. Commencing from the outside, these are as follows:—

(1) The *cuticle* (Text fig. 8, *a.*) is an extremely thin structureless layer covering the whole of the chitinous exoskeleton. Its continuity is interrupted at intervals where the ducts of the cutaneous glands open to the exterior. From the cuticle there arise numerous small papillae, which are only seen when examined under the microscope. These must not be confused with the setae, which are visible to the naked eye and which have an entirely different structure (see below).

(2) The *pigmented layer* (*b.*) is a moderately-thick layer containing pigment. In the hard parts of the exoskeleton this layer is calcified. It has a laminated structure, and the numerous layers of which this portion of the exoskeleton is composed are parallel to the surface.

(3) The *calcified layer* (*c.*) is the broadest layer of all

\* Cuénot, L. "Études physiologiques sur les Crustacés Décapodes." *Archives de Biologie*, T. XIII, p. 245.



in the fully-formed exoskeleton. It is colourless and richly impregnated with calcareous salts. Like the previous layer, it exhibits striations parallel to the surface, but the laminae are generally broader than in the pigmented layer. It is to this layer that the great thickness and hardness of the shell in a hard crab are due, as new laminae are constantly being added to this region until the exoskeleton attains its maximum thickness.

(4) The *non-calcified layer* (*d.*) is a very thin layer composed of delicate laminae parallel to the surface. This layer remains in a very soft condition, and is not formed until the calcified layer has attained its maximum width.

Vertical sections through the integument reveal the fact that there are striations in the chitin at right angles to the surface, as well as the horizontal lamellae already referred to. Also, as Vitzou has pointed out, in horizontal sections the chitinous integument is divided up into small hexagonal areas, and in each of these areas small pores are present. Vitzou determined that these areas were of the same size and shape as the horizontal sections through the cells of the epidermis. He concluded, therefore, that the exoskeleton is composed of innumerable hexagonal prisms packed side by side, having their long axes at right angles to the surface of the body. Furthermore, each of these chitinous prisms is in contact with the outer end of an epidermal cell. So that for every cell of the epidermis there is a corresponding prism forming a unit of the chitinous exoskeleton. Such an explanation accounts for the presence of the vertical striations in vertical sections, and for the polygonal areas in the horizontal sections. The small pores in the middle of these areas are due to the presence of numerous fine canals traversing each prism from the epidermis to the exterior.

### Mode of Formation of the Exoskeleton.

Originally the exoskeleton was believed to be produced by a secretion from the cells of the epidermis. Vitzou, however, claimed that the process is effected in a different manner. According to him the new shell is produced in the following way. The contents of each epidermal cell becomes modified at the outer margin. This outer part becomes cut off from the rest of the cell. Thus at this stage the epidermis is covered by a thin layer, which, however is not one homogeneous whole, but is divided up into numerous polygonal areas, each area corresponding in shape and position to an epidermal cell. The process is repeated; the outer part of each cell is again cut off, and at this stage we have a two-layered polygonal cylinder above each cell. This process is repeated until we have built up over each cell a multi-layered cylinder. Since the cells of the epidermis lie close together, the chitinous cylinders are also tightly packed and form what appears to be a continuous exoskeleton. The striations parallel to the surface of the integument represent the successive lines of growth. Thus, according to Vitzou, the process of formation of the chitinous integument consists in the successive thickening of the outer walls of the epidermal cells.

### Setae.

These are long hair-like processes which project from the exoskeleton in various regions of the body. In sections each seta is seen to arise from the region of the epidermis as a narrow tube enclosing a cavity. This tube passes through the chitinous layers and projects from the exterior as a long narrow process. Its walls are cuticular and are continuous with the thin structureless cuticle

covering the chitinous integument. So that wherever a seta arises the continuity of the thick exoskeleton is broken in order to allow this tube-like prolongation to reach the exterior. The contents of the setae are protoplasmic and are connected with the epidermis. In some regions of the body the setae have nerve fibres passing to their interior. These are the *sensory setae*, of which there are several kinds (see section on Sense Organs). The setae may be simple prolongations, or they may consist of a central axis, from which arise off-shoots. In the latter case the cavity of the central axis is not continued into the lateral out-growths. In addition to the setae described above, there are small papillae on the surface of the shell, which are merely thickenings of the cuticle and do not contain a cavity. Vitzou states that in *Portunus* these cuticular processes are comparatively long. In *Cancer*, however, they are extremely small, and can only be detected under the microscope. Vitzou affirms that the long "setae," present in the walls of the fore-gut, have no central cavity, and are probably merely extremely large cuticular prolongations and not true setae. These "setae" in the fore-gut act as strainers. Where the sub-branchial region of the carapace is closely applied to the bases of the thoracic legs there is a rich growth of setae. These probably assist in preventing the water from entering the branchial chamber at the base of the thoracic legs.

The inhalent branchial opening is also well guarded by long setae, both on the flabellum of the third maxilliped and on the anterior border of the coxopodite of the chela. The setae on the endopodites of the pleopods in the female are used for the attachment of the eggs.

## Cutaneous (or tegumentary) glands.

Scattered throughout the connective tissue, near the basement membrane, are globular masses of cells, each cellular clump being connected with the exterior by a fine duct. These are the cutaneous glands. Each cell of the globular mass is in contact with a small cavity on its inner side. This central cavity of the glandular mass receives the secretion from the various cells. The cavity is connected with the duct, and thus the glandular secretion is enabled to pass to the exterior. The duct is lined by a fine protoplasmic wall. The wall of the duct probably represents a single cell, in which case the cavity of the duct is intracellular. The gland cells and the duct cell are all modified epidermal cells.

The cutaneous glands are scattered throughout the integument, and in some regions are extraordinarily abundant. The glands present in the mandibles and in the walls of the oesophagus, and also those in the hind-gut, have a similar structure to the ordinary glands on the surface of the body. They are, in fact, modified cutaneous tegumentary glands.

Immediately in front of the mouth there is a compact mass of cutaneous glands at each side, which open on the surface of the epistoma. These glands have the structure of the typical cutaneous glands, but are extremely large. They are about four times as large as those present in the walls of the oesophagus (see section on Alimentary Canal). Similar glands are found also in the metastoma, packed very closely together. Herrick\* has also observed them in the same regions in the lobster. (See fig. 60.)

In the floor of the branchial chamber there is a well-defined transverse ridge lying in front of the inhalent

\* Herrick. "The American Lobster." *Bull. U.S. Fish Com.*, Vol. XV., 1895.



branchial aperture. The epidermis in this region presents a very interesting condition, and there appear to be numerous modified cutaneous glands.

There are also great numbers of cutaneous glands present on the endopodites of all the maxillipedes.

On the endopodites of the pleopods of the female there are closely-packed tegumentary glands. According to Herrick, these secrete the cement which attaches the eggs to the endopodites of the abdominal appendages.

The function of the various tegumentary glands in various parts of the body is not clearly known. Lang\* states that some have an excretory function. There is little doubt that the functions of these glands differ in various regions of the body. Those, for example, on the pleopods are extremely specialised. It is not inconceivable that the glands in the integument of the epistoma and metastoma may produce a secretion which is poured on the food as it enters the mouth.

The glands in the walls of the oesophagus are probably salivary glands. Herrick thinks that this explanation of their function no longer holds good, since glands of similar structure have been found in the walls of the hind-gut. This argument, however, does not carry much weight, if we recognise that *all* the tegumentary glands (both on the surface and in the walls of the alimentary canal) have the same essential structure, and yet are capable of performing different functions in various regions of the body.

#### ECDYSIS.

The epidermis of all Arthropods is covered by a continuous layer of chitinous integument, which may become calcified in certain regions. This outer integu-

\* Lang. *Text-book of Comparative Anatomy*, Part I.

ment is continuous with the chitinous lining of the fore-gut and hind-gut. The body, therefore, may be said to be enclosed in an inflexible coat, which prevents the tissues from expanding. The growth of the animal cannot be gradual, but can only take place when the animal breaks through the stiff outer covering. Immediately after exuviation, the animal, which is then only covered by an extremely thin flexible membrane, will increase in size. This process of casting, or **ecdysis**, is characteristic of all Arthropods. Ecdysis takes place periodically, and growth can only take place while the animal is in a "soft" condition.

In Cancer, when ecdysis is about to take place, the carapace opens along the pleural groove at each side. These two longitudinal splits become connected posteriorly with a transverse opening, which makes its appearance between the posterior border of the carapace and the tergum of the first abdominal somite. Thus the tergal region of the carapace is free from the remainder of the exoskeleton, except along a line marking the posterior boundary of the first cephalic sternum. The carapace, therefore, acts like a lid of a box, and is hinged anteriorly. The first part of the body to be withdrawn from the old shell is the abdomen, which is followed by the various legs. When all the parts are completely free the crab emerges from beneath the hinged carapace.

On the dorsal sides of the basi-ischium and meros of the chela there are faint grooves (Pl. II, fig. 12, *abs.*). These are the "lines of absorption," and at the time of ecdysis the exoskeleton of the chela loses its calcification at these points. In this way the withdrawal of the large claw is effected, as it would be extremely difficult for the chela to be withdrawn if the integument at the base of the limb remained hard.

As pointed out by Vitzou,\* the method of ecdysis in the *Macrura* differs from that found in the *Brachyura*, because in the latter the abdomen is withdrawn first. In the *Macrura* the thorax is first withdrawn, and the abdomen leaves the old shell last.

The tissues of the animal become greatly changed immediately before ecdysis. The blood increases enormously in volume, and Witten† suggested that the increase is due to the absorption of water by means of the digestive gland. He presumed that this excess of blood plasma produced the internal pressure necessary for ecdysis and growth. The muscles become very soft and semi-fluid, and the fibres lose their well-defined outlines and cross-striations.

The digestive gland probably increases in size during ecdysis. The fat cells are stocked with glycogen, the ferment cells are much bigger, and the colour of the ferment vesicle is of a deep brown colour, thus giving the digestive gland a deeper colour at this period. The reproductive organs are generally in an immature condition at the time of ecdysis.

Immediately before and after ecdysis the crabs are unfit for food. They are "watery" and have a bitter taste. Reference is made in the Economic section to the "Granny" crabs, which are considered by the fishermen to be diseased crabs. I have reason to believe that they are merely crabs preparing for ecdysis.

One of the most interesting changes which accompany ecdysis is probably the formation of the new integument, as a result of the extreme activity of the epidermal cells. This new exoskeleton is already formed when the hard shell is discarded.

\* Vitzou. *Arch. zool. exp. et gén.*, T. X, 1882.

† Report on the Scientific Investigations, Northumberland Sea-Fisheries Committee, 1903.

Before ecdysis the cells of the epidermis become greatly elongated, and in the underlying dermis the cells of Leydig, which are rich in glycogen, become extremely numerous. The supply of reserve food material in these cells is evidently of the utmost importance at a time when growth and regeneration of the tissues is taking place. At the time when the crab is preparing to cast, a new chitinous layer is formed by the epidermis. This new layer is separated from the old shell by a gelatinous fluid. The chitinous layer, which is the first appearance of the new exoskeleton, consists of two parts—an outer structureless cuticular layer, and an inner chitinous layer containing pigment. This inner layer represents the pigmented layer. The calcified and non-calcified layers are not produced until after ecdysis. The calcified layer grows throughout the greater part of the period until the next ecdysis, and it is to this layer that the hardness and increasing thickness of the shell is due.

Vitzou's theory explaining the method of formation of the exoskeleton has been described above (see section on Integument).

The frequency of casting and other problems connected with ecdysis are discussed below in the section on Economics.

#### AUTOTOMY AND REGENERATION OF LIMBS.

One of the most interesting and characteristic features in the natural history of the crab is the power the animal possesses of throwing off injured limbs (**autotomy**) and of forming new limbs to replace the old (**regeneration**).

The processes associated with these phenomena may be briefly stated as follows:—

If the distal portion of one of the pereiopods be



seriously injured, the crab immediately throws off part of the limb. The whole limb is not sacrificed. The self-amputation always takes place along the thin groove present on the basi-ischium representing the line of separation between the basipodite and ischiopodite. This groove, therefore, may be said to surround the **fracture plane** (Pl. II, fig. 12, *f.p.*).

When autotomy has been effected, the fracture plane is seen to be covered by a thin membrane, or **diaphragm**, which is perforated, slightly below the centre, by a small foramen. The blood flows out through this small opening, but soon coagulates, forming a clot over the mouth of the foramen and also on the outer surface of the diaphragm.

The diaphragm with its outer coating of coagulated blood assumes a dark brown colour in a few days, and ultimately becomes quite black. This black coating is worn away in course of time, and reveals a thin membrane extending across the stump.

Beneath the membrane a small papilla makes its appearance, and marks the commencement of the regeneration of the limb.\*

### Conditions necessary for Autotomy.

The successful performance of self-amputation in Cancer depends upon several conditions, of which the most important are discussed below.

#### 1. *The crab must be healthy.*

This is a most important factor. Animals which are in a diseased or weak condition, or which have been kept out of water for a considerable time, and in which, as a

\* According to Williamson, the regeneration only takes place when the crab is preparing for ecdysis. The limb does not attain its full size at the first moult after regeneration. Two or three moulting processes must take place before the limb attains its normal size.

consequence, the nerve responses are feeble, do not perform autotomy very readily.

2. *The nerve of the limb must be sufficiently stimulated.*

This appears to be a self-evident proposition. Whatever may be the cause of autotomy, and whatever may be the reason of this complex phenomenon, it is without doubt the result of nervous stimulation. But the question as to what is a "sufficient" stimulation cannot be disposed of so easily (see below under the general discussion on Autotomy).

3. *The thoracic nerve mass must remain intact.*

We are indebted to Fredericq\* for his investigations on the physiological processes involved in autotomy. He has proved that the latter is the result of a reflex, and that the thoracic ganglion belonging to the appendage is the centre of this reflex. The brain is the seat of voluntary and co-ordinated movement in Cancer, and if the brain be removed autotomy will still take place. If, on the other hand, the thoracic nerve mass be removed or destroyed, self-amputation cannot proceed. The afferent nerve fibres which are stimulated as the result of injury to the limb are connected with the ganglion cells of the thoracic nerve mass, and from these the efferent fibres pass to the extensor muscle of the basi-ischium. This muscle is the one concerned in the autotomy, and thus we are provided with a fourth condition.

4. *The integrity of the extensor muscle of the basi-ischium must be maintained.*

The first movement after the limb has been injured is the extension of the basi-ischium; i.e., it moves in a dorsal direction. This movement continues until the

\* Fredericq, L. "Nouvelles recherches sur l'autotomie chez le crabe." *Archives de Biologie*, T. XII, 1892.

distal portion of the limb comes into contact with the carapace or with some other fixed object, when the limb breaks at the fracture plane. That this upward movement, or extension, of the basi-ischium is necessary for autotomy may be proved by cutting the extensor muscle (or muscles), and then injuring the limb. No self-amputation will then take place. If the flexor muscle be cut, and the extensor remain uninjured, autotomy will proceed.

5. *The distal portion of the limb must come into contact with some point of resistance.*

This condition has been emphasised above. As soon as that part of the limb on the distal side of the fracture plane comes into contact with some point of resistance (e.g., the carapace) the upward movement of this portion is stopped. The proximal portion of the basi-ischium, however, still continues to move upwards under the influence of the extensor muscle. Thus there are two forces acting on the fused basi-ischium—a force at the proximal end tending to move the segment upward, and a force at the distal extremity preventing this upward movement. A great strain is produced on the basi-ischium and it snaps at its weakest point, which is the fracture plane.

6. *The stimulation to produce autotomy must be applied between the fracture plane and the distal end of the propodite.*

The nerve does not pass into the dactylopodite, so that if the latter segment be wounded the nerve will not be stimulated. It is equally futile if the limb be damaged on the proximal side of the fracture plane.

Amongst the Brachyura two kinds of autotomy have been recognised.

(1) If the crab is captured by means of one of its limbs it will throw off the limb in order to escape from its enemy ("evasive autotomy").

It is evident that all Decapods do not act similarly under such conditions. It does not appear to be the case in Cancer or Carcinus. Fredericq's researches led him to believe that crabs did not throw off legs in order to escape from enemies, but his experiments were confined to a few species. Taking all the evidence available, it would appear that autotomy does take place under the above conditions in some crabs, such as the Maiidae and the Grapsidae.

(2) If one of the legs of a crab be severely wounded, the limb will be thrown off. This probably occurs without exception in the Brachyura.

It is well to remember that in both cases we are probably dealing with essentially similar physiological conditions. In both cases the autotomy is produced as the result of the stimulation of the nerve of the leg, and the difference appears rather to be one of degree than of kind. In both the above cases the autotomy is produced as the result of a reflex, and the seat of this reflex is in the ganglion of the somite to which the autotomised leg belongs.

Quite recently, Piéron\* has concluded that there is still another kind of autotomy which is purely voluntary, and will not take place after the commissures connecting the cerebral ganglia with the thoracic mass have been cut. One of his experiments with Grapsus was as follows:—A leg of the crab was tied to a stake within view of a

\* Piéron, H. *C.R. Soc. Biol.*, 11th May, 1907. *Ibid.*, T. LXIII (1907), Nos. 33 and 34.



sheltered crevice in the rocks. The crab discarded the imprisoned limb as a conscious effort in order to reach the inviting shelter. This did not happen if the brain were destroyed or if the commissures were cut ("psychic autotomy").

It is difficult at the present juncture to accept Piéron's explanation, as Mlle. Drzewina† has also performed similar experiments with *Grapsus*, and has obtained entirely different results. But so far as *Cancer* is concerned, the "psychic autotomy" does not appear to be present.

It is not possible in the present state of our knowledge to arrive at a definite conclusion with regard to the full significance of the processes involved in autotomy. But whatever may have been the lines along which autotomy has been evolved, there is no doubt that one of its most important objects is the prevention of bleeding. If the arthrodial membrane between an appendage and the body be cut, the crab will probably bleed to death, and this appears to be one of the greatest dangers with which the animal has to contend. The limbs, on account of their position and size, are continually in danger of being torn or crushed. If the limb were seriously injured, and autotomy did not take place, the crab would bleed to death, because the wounded surface would probably be too large to allow coagulation to take place. This difficulty is surmounted by the limb being thrown off at the fracture plane, across which, as we have already seen, a membrane is stretched. This membrane is perforated by a small foramen through which pass the nerve and blood streams connecting the proximal and distal parts of the appendage. Over this foramen a clot may readily be formed, and thus the excessive bleeding may be prevented.

† Drzewina, A. *C.R. Soc. Biol.*, T. LXIII (1907), Nos. 33 and 34.

## Histology. (Text fig. 9).

**Before autotomy.** A longitudinal section through the basi-ischium of a pereopod in which autotomy has not been effected displays the following structure (9A.).

In the region of the fracture plane the exoskeleton is discontinuous, the plane of the discontinuity being at right angles to the longitudinal axis of the basi-ischium. The break is not always easily detected, as the two parts fit very closely together.

On the inner side of the exoskeleton is the normal layer of epidermis (*ep.*). At the plane of breaking the epidermis turns inward both at the distal extremity of the basipoditic region and also at the proximal end of the ischiopodite. These ingrowths extend as far as the central nerve and blood vessels, where the epidermal ingrowth of the basipodite (*i.*) becomes continuous with that of the ischiopodite (*o.*). In other words, across the plane of fracture the epidermis underlying the exoskeleton is not directly continuous, but becomes turned inward as far as the central nerve of the leg.

Thus there is a double diaphragm stretching across the leg in the fracture plane, and near the centre of this double membrane there is a small opening which permits of the passage of the nerve (*n.*) and blood vessels from one side to the other. The walls of this narrow opening are composed of a cellular membrane, which connects the proximal and the distal diaphragms.

**After autotomy.** The ischial portion of the exoskeleton is broken away at the fracture plane, and the underlying structures belonging to the ischium have also been torn away. These include the epidermis of the ischium and also the distal portion of the diaphragm. Stretching across the broken end of the stump (Text

fig. 9, B.) is a membrane representing the proximal portion of the double diaphragm (*i.*). Near the centre of this is a small foramen. In sections taken immediately after autotomy there is a layer of coagulated blood (*b.*) on the outer side of the diaphragm.

The torn edge of the diaphragm in contact with the foramen appears to grow over the latter. Thus, shortly after the autotomy has been effected, there is a continuous membrane or diaphragm covering the broken stump (9 C.). This membrane is composed of a single layer of epidermal cells, which is continuous with the epidermis underlying the exoskeleton of the basipodite. On the outer side of the membrane is a layer of coagulated blood. On the inner side of the ectoderm of this membrane, and lying close to it, there appears to be a continuous layer of connective tissue fibres. Miss Reed\* describes also the presence of a dense mass of blood cells immediately beneath the membrane.

**Regenerative process.** Shortly after autotomy has taken place the cells of the diaphragm begin to degenerate (Text fig. 9, D.). Ultimately there is on the outside of the stump a layer of dead tissue, formed of an outer layer of coagulated blood, beneath which is the layer of degenerate epidermal cells. According to Miss Reed, there is also an inner layer of degenerate blood cells. The dead epidermal cells of the diaphragm become disconnected from the epidermis underlying the exoskeleton of the limb, and this epidermis grows inward beneath the dead outer layer. This takes place from all sides, and the in-growing cells meet in the centre and form a single

\* Unfortunately I did not have access to Miss Reed's paper on the histological processes in connection with autotomy until after my own observations had been made. My results, in the main, however, bear out the conclusions arrived at in her paper (*Bryn Mawr College Monographs*, Reprint Series, Vol. V, 1905).

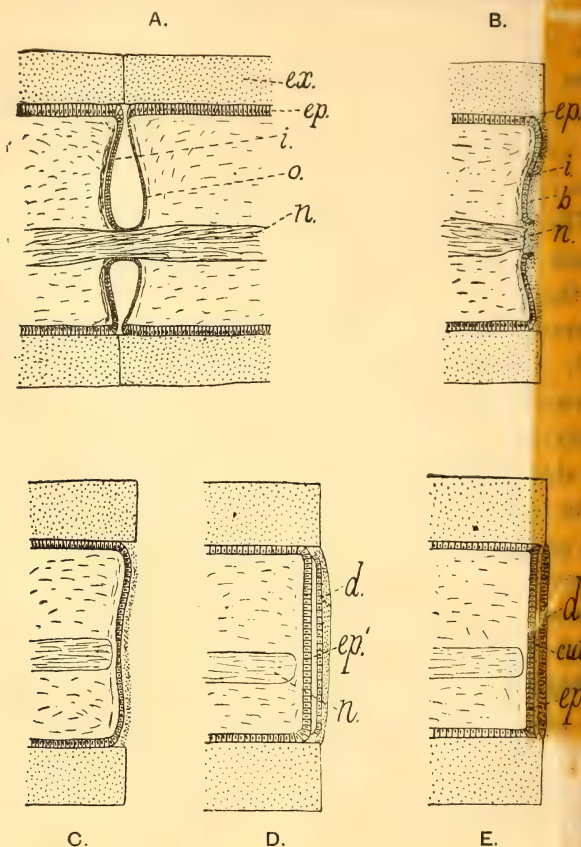


FIG. 9.—Diagrams to illustrate the histology of the structures in the fracture plane before and after autotomy. (In all the diagrams the proximal end of the limb is to the left).

A. = longitudinal section through basi-ischium before autotomy, showing the double nature of the diaphragm.

B. = longitudinal section through the basipodite immediately after autotomy. Showing the single diaphragm and the foramen.

C. = longitudinal section through the basipodite shortly after autotomy. The epidermis of the diaphragm has grown over the foramen.

D. = the degeneration of the diaphragm and the formation of a new layer of epidermis beneath.

E. = Formation of a thin cuticle (which is continuous with the exoskeleton) by the new epidermis.

ep. = epidermis.

ex. = exoskeleton.

i. = proximal part of diaphragm.

o. = distal part of diaphragm.

ep'. = new epidermis.

n. = nerve of the appendage.

b. = coagulated blood.

d. = degenerated diaphragm and blood tissue.

cut. = new cuticle formed by the new epidermis.



layer of cells beneath the outer dead layer. Eventually a thin layer of chitin is secreted on the outer side of these cells (Text fig. 9, *E.*), and this layer of chitin is continuous with the exoskeleton. The old membrane, which is now almost black, becomes worn off, and this new chitinous membrane is exposed.

The cells in the new layer of epidermis become extremely active, and increase in number internally. At first an undifferentiated mass of cells is formed beneath the membrane, but gradually differentiation takes place and the new parts of the limb are laid down in miniature. As they increase in size they grow outward, and form a small papilla on the stump.

## MUSCULAR SYSTEM.

(Pls. III, IV).

### MUSCLES OF THE CEPHALOTHORAX.

I. *E y e*. The ocular peduncle consists of two parts—an inner rod-like portion extending inwards as far as the middle line, and an outer swollen portion at the free end of which is the visual organ. The outer portion articulates with the inner, and is connected with the latter by means of a flexible membrane. The movement of the outer portion is effected by two small muscles—a ventral flexor and a dorsal extensor.

II. *F i r s t a n t e n n a*. The muscles are extremely small. The basal segment of the protopodite has a dorsal extensor and a ventral flexor. In their natural condition the second and third segments are flexed. In both cases the extensor is on the inner side and the flexor muscle is on the outer side.

III. *Second antenna*. The basal region of this appendage is fused with the carapace, and the muscles have degenerated. The operculum, which probably represents the coxopodite, is still freely movable, but its extensor and flexor muscles have now another function in connection with the raising and closing of the operculum. The whole question of the homology of the opercular muscles has been fully discussed by Marchal.\* The flagellum has not much movement, and its muscles are very small.

IV. *Mandible* (fig. 31). There are two sets of muscles—the adductors for closing the mandibles and the abductors for opening the mandibles.

*External adductor muscle (e.a. md.)*. Arises as a broad band from the anterior and outer portion of the sub-hepatic region of the carapace. It passes inwards and upwards, and is inserted on a long tendon attached to the outer part of the mandibular apophysis.

*Internal adductor muscle (i.a. md.)*. Arises from the urogastric region of the carapace. It passes downwards and forwards as a short broad muscle, and is inserted on an extremely long narrow tendon attached to the posterior margin of the mandible.

*External abductor muscle (e.b. md.)*. Arises from the posterior and inner corner of the hepatic region of the carapace. It passes directly downwards, and is inserted on a narrow tendon attached to the posterior side of the apophysis. This muscle is comparatively small.

*Internal abductor muscle (i.b. md.)*. Arises from the top of the vertical rod-like portion of the first post-oral endopleurite. It passes outwards and forwards, and is attached to the outer part of the apophysis.

\* Marchal. "Appareil excréteur des Crustacés Décapodes." *Archives Zool. exp. et gén.* (Ser. 2), T. X, 1892.

V. **F i r s t m a x i l l a** (fig. 26). There are two extensors and two flexors.

*Flexors.* One outer (*o.e.m.*) and one inner (*i.e.m.*) muscle, which run together and arise from the outer portion of the protogastric region of the carapace. They pass directly downwards together, and when near the maxilla the two separate and are inserted on the outer and inner parts of the coxopodite respectively.

*Extensors.* One outer (*o.f.m.*) and one inner (*i.f.m.*) The tops of the two pillar-like portions of the first post-oral endopleurites are joined by a strand of tissue. Beneath the arch thus formed the two muscles arise near the middle line. They pass downwards and slightly inwards, diverging somewhat as they approach the appendage. They are inserted on the coxopodite at the same point as the corresponding flexor muscle.

VI. **S e c o n d m a x i l l a**. There are two extensors and two flexors.

*Extensors.* The inner extensor arises from the posterior face of the first post-oral endopleurite. It is a short muscle which passes downwards and slightly outwards, and is inserted on the outer side of the coxopodite.

The outer extensor is a long narrow muscle. It arises from the epimeron of this somite just in front of the last cephalic endopleurite. It passes inwards and downwards across the anterior face of the flexors of the scaphognathite, and is inserted close to the small inner extensor.

The two *flexors* are small, and arise close together near to the origin of the outer extensor. They pass directly downwards, and are inserted near together on the inner side of the coxopodite.

The **Scaphognathite** (figs. 27, 28) has a complex movement, and the plane of motion is roughly at right angles to its long axis. There are two sets of muscles—extensors which pull the organ downwards, and flexors which draw it up again to its natural position. In the upward movement the scaphognathite does not remain flat, as when in a position of rest, but it becomes curved so that the upper side is concave. This is effected by a set of accessory muscles. The latter extend into the leaf-like portion of the scaphognathite, and do not stop at the edge of the organ, as do the other muscles.

All the flexors arise from the anterior face of the last cephalic endopleurite. Their names have been given according to the position of insertion on the scaphognathite. The flexors are inserted on the anterior wall of the base of the scaphognathite.

*Inner flexor (i. e. s.)* A long narrow muscle arising from the upper part of the endopleurite. It passes down the latter and, turning slightly inwards; it is inserted on the innermost part of the base of the scaphognathite. It has a small branch which arises from the side of the epimeron.

*Outer flexor (o. e. s.)* An extremely broad muscle, which arises immediately beneath the origin of the previous muscle and also on its inner side. It passes down the endopleurite parallel to the epimeron, and is inserted on the extreme outer edge of the base of the scaphognathite.

*Outer median flexor (o. m. e.)* A long and fairly broad muscle, arising from the extreme inner border of the endopleurite above the large foramen of the latter. It passes downwards and outwards across the front of the foramen, and is inserted on the base of the scaphognathite on the inner side of the previous muscle.



*Inner median flexor (i. m. e.)* A very short muscle arising from the endopleurite near the middle of the base of the foramen. It passes downwards below the other flexors and is inserted at the base of the scaphognathite on the outer side of the inner flexor.

The extensor muscles are situated beneath the flexors, so that it is necessary to cut away the latter in order to expose the extensors. There is one extensor corresponding to each flexor, and the insertion of each extensor is near to that of the corresponding flexor. All the extensors arise at the base of the anterior face of the last cephalic endopleurite. They are all short muscles, and are inserted on the posterior wall of the base of the scaphognathite.

*Inner extensor (i. f.)* Arises at the base of the endopleurite. It passes inwards and is inserted close to the inner flexor.

*Inner median extensor (i. m. f.)* It lies immediately below the inner median flexor, and above the three other extensors. It arises about the middle of the base of the endopleurite and passes downwards and forwards. Its insertion is close to that of the inner median flexor.

*Outer median extensor (o. m. f.)* Its origin is on the inner side of the previous muscle. It passes obliquely outwards and forward beneath the previous muscle, and is inserted close to the insertion of the outer median flexor.

*Outer extensor (o. f.)* A very short and broad muscle arising on the outer side of the origin of the inner median extensor. It passes outwards and downwards and is attached to the scaphognathite close to the insertion of the outer flexor.

The last two muscles have their insertions situated in the thickened bulb-like portion of the scaphognathite.

The accessory muscles are situated entirely within the scaphognathite itself. Their function is to bend the scaphognathite during the process of lifting up or extending the latter.

There are two muscles which arise close together on the inner side of the insertion of the inner flexor of the scaphognathite. They extend outwards into the middle and inner portions of the scaphognathite.

The *anterior accessory* (*a. acc.*) divides into two parts, each of which is attached to the anterior wall of the scaphognathite.

The *posterior accessory* (*p. acc.*) also divides into two parts. One division appears to be inserted on the posterior wall and the other on the anterior wall.

VII. **FIRST MAXILLIPED** (fig. 29). Only the extensor and flexor of the **Coxopodite** need be noted here.

The *extensor* (*e. C.*) arises on the epimeron of this somite. It passes downwards and inwards between the two flexors of the flabellum and behind the extensor of the latter (see below). It is inserted near the outer and posterior margin of the coxopodite.

The *flexor* (*f. C.*) arises at the upper side of the posterior face of the last cephalic endopleurite on the inner side of the point where the latter fuses with the second thoracic endosternite. It passes directly downwards as a narrow muscle, and is inserted on the anterior margin of the coxopodite.

The muscles of the exopodite have the same arrangement as the similar parts in the third maxillipede.

The muscles of the **flabellum** are large and powerful. The flabellum lies on the dorsal side of the gills, and by repeated rhythmical movements keeps the surface of the gills free from sand and mud.

The *extensor* (*ex. fl.*) is a short broad muscle arising from the upturned edge of the sternum in this somite. It passes outwards across the mouth of the cavity of the coxopodite, and is inserted on the inner side of the base of the flabellum.

The *anterior flexor* (*a.f.fl.*) is a fairly broad muscle arising from the posterior face of the last cephalic endopleurite, immediately above the foramen of the latter. It passes downwards, and is inserted on the anterior edge of the base of the flabellum.

The *posterior flexor* (*p.f.fl.*) is an extremely broad muscle arising from the last cephalic endopleurite, above the origin of the previous muscle. It runs downwards behind the extensor of the coxopodite, and is inserted on the posterior edge of the base of the flabellum.

VIII. **Second maxillipede.** This appendage is similar to the third maxillipede in structure, and its muscles have the same arrangement (see below).

The extensor muscle of the coxopodite arises from the inner side of the second thoracic epimeron, and the flexor arises from the upper end of the anterior face of the second thoracic endosternite. All the muscles of the basi-ischium are attached to the lower end of the anterior face of the second thoracic endosternite. The muscles of the flabellum are quite small, but have the same parts as described in the first maxillipede.

#### IX. Third maxillipede (fig. 30).

**Coxopodite.** There is a small extensor and a larger flexor.

The *extensor* muscle arises on the inner side of the third thoracic epimeron, and is inserted on the outer side of the coxopodite by means of a narrow tendon (*ex. C.*).

The *flexor* muscle is attached to the anterior wall of

the third endosternite. It passes outwards, and is inserted on a broad tendon (*f. C.*) at the inner side of the coxopodite.

**Basi-ischium.** There are two chief muscles.

The *extensor* is a small muscle arising from the anterior wall of the third thoracic endosternite. It is inserted on the ventral side of the basi-ischium by means of a small tendon (*ex. B.*).

The *flexor* is a larger muscle arising near the origin of the extensor. It is inserted on a long tendon (*f. B.*) on the dorsal side of the basi-ischium. There is also a small accessory flexor inserted on the outer side of the larger flexor.

There is one flexor and one extensor for each of the remaining segments of the endopodite. The muscles of the meropodite and carpopodite are fairly large. Those of the propodite and the dactylopodite are small.

The **exopodite** has two small muscles—a dorsal extensor and a ventral flexor.

The **flagellum** of the exopodite is flexed in its natural position. There is a large *extensor* muscle (*ex. fl.*) running the whole length of the exopodite, which is attached to the outer edge of the flagellum and by its action raises the latter. I have not been able to make out a flexor muscle. Probably the flagellum falls back into its natural flexed condition by means of the elasticity of the arthrodial membrane.

The flagellum in each of the maxillipedes is very active, and is constantly moving with great rapidity.

#### X. Chela.\* (fig. 21, Text fig. 10).

**Coxopodite.** There are two muscles—a posterior

\* In all the pereopods it is probable that those muscles which are situated in the dorsal region of the pleural muscle chambers arise, not only from the walls of the latter, but also from the carapace in this region (Pl. IX, fig. 56, *fl.m.*)



extensor pulling the coxopodite backward and an anterior flexor pulling it forward.

The *extensor* is situated in the outer and posterior region of the fourth thoracic pleural muscle chamber. It arises from the anterior and posterior walls of the latter and passes forward and downward. Its insertion is on a long narrow tendon arising from the posterior side of the coxopodite (fig. 21, *ex. C.*, Text fig. 10, *d.*).

The *flexor* is a much larger muscle than the extensor, and lies in the fourth thoracic sternal muscle chamber. It arises from three parts of the endophragmal system—(1) from the posterior face of the third thoracic endosternite; (2) from the inner side of the third endopleurite; and (3) from the anterior face of the fourth thoracic endosternite. It passes downward and forward, and is inserted on an extremely broad tendon on the anterior side of the coxopodite (fig. 21, *f. C.*, Text fig. 10, *c.*).

**Basi-ischiopodite.** There are two extensors and three flexors inserted on the proximal region of this segment.

The *anterior extensor* is situated in the anterior and ventral portion of the fourth thoracic pleural muscle chamber. It arises from the ventral part of the anterior and inner walls of the chamber. It runs outward, and is inserted on a long and narrow tendon situated immediately above the anterior hinge (fig. 21, *a. ex. B.*, Text fig. 10, *f.*).

The *posterior extensor* is a small muscle situated almost entirely in the base of the coxopodite. It is attached to the ventral part of the wall of the fourth pleural muscle chamber. It passes outward, and is inserted on a small tendon which is immediately above that of the anterior extensor (fig. 21, *p. ex. B.*, Text fig. 10, *e.*)

The *anterior flexor* lies in the ventral region of the

fourth sternal muscle chamber, and arises from the fourth thoracic sternum. Its course is outward, upward and backward, and at its outer extremity it is inserted on a broad tendon lying on the ventral side of the basi-ischium, mid-way between the two hinges (fig. 21, *a. f. B.*, Text fig. 10, *k.*).

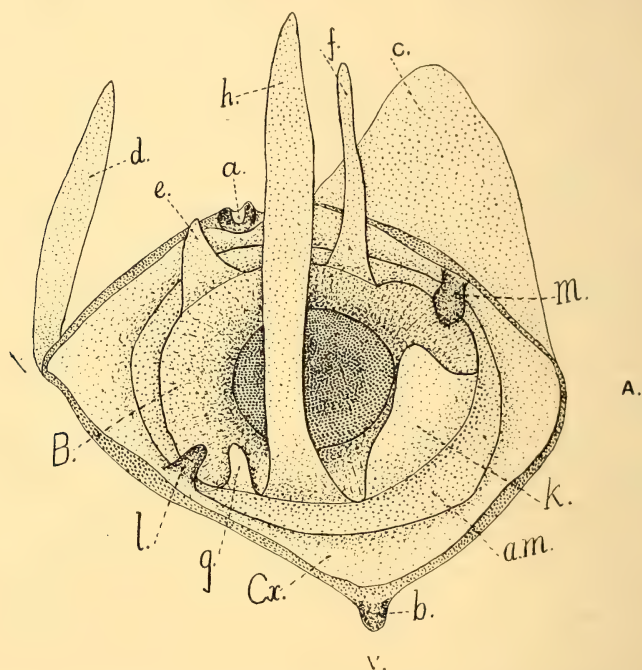


FIG. 10.—The proximal end of the chela, after all the soft tissues have been removed. The tendons of the muscles moving the coxa and basi-ischium are shown. (The upper side of the figure is dorsal, and the right side is the anterior end.)

*Coxopodite*.—*a.* = dorsal hinge; *b.* = ventral hinge; *c.* = tendon of flexor muscle; *d.* = tendon of extensor muscle.

*Basi-ischium*.—*e.* = posterior extensor muscle; *f.* = anterior extensor muscle; *g.* = lesser posterior flexor muscle; *h.* = greater posterior flexor muscle; *k.* = anterior flexor muscle; *l.* = posterior hinge; *m.* = anterior hinge.

The *greater posterior flexor* lies in the outer and anterior portion of the fourth pleural muscle chamber,

and its origin is on the anterior wall of the latter. It passes downward behind the anterior extensor, and is inserted on an extremely long tendon which arises from the joint immediately behind the tendon of the anterior flexor (fig. 21, *p. f. B.*, Text fig. 10, *h.*).

The *lesser posterior flexor* is situated on the inner and anterior region of the fourth pleural chamber. It passes outward, and is inserted on a small tendon in front of the posterior hinge (Text fig. 10, *g.*).

The **Meropodite** has very little movement, and the muscles are extremely small.

The *extensor* is a small muscle arising from the posterior wall of the ischium. It passes downward and backward, and is inserted on a small tendon on the ventral side of the meros (fig. 21, *t. ex. M.*).

There does not appear to be a definite flexor muscle, but when the extensor muscle relaxes, the weight of the distal portion of the limb is sufficient to produce the small amount of flexion necessary.

**Carpopodite.** There is an anterior flexor and a posterior extensor muscle.

The *extensor* arises from the posterior walls of the meros throughout its entire length. The insertion of the muscle is on a long tendon situated near the dorsal hinge of the carpos. This tendon lies in the dorsal part of the meros and extends almost to the proximal end of the latter (*ex. C.*<sup>1</sup>).

The *flexor* has its origin on the anterior walls of the meros. Its tendon is similar in size to that of the extensor. It lies in the ventral region of the meros, and arises from the antero-ventral border of the carpos (*f. C.*<sup>1</sup>).

**Propodite.** There is a posterior extensor and an anterior flexor muscle.

The *extensor* arises from the posterior walls of the

carpos, and is inserted on a broad tendon at the posterior side of the propodite (*ext. P.*).

The *flexor* has its origin on the anterior wall of the carpos, and is inserted on a large tendon at the anterior side of the propodite (*f. P.*).

**Dactylopodite.** There is a dorsal extensor and a ventral flexor.

The *extensor* is comparatively small, and arises from the dorsal or posterior walls of the propodite. It is inserted on to a narrow tendon which is situated immediately above and between the two hinges of the dactylos (*ext. D.*).

The *flexor* is an extremely large muscle which occupies the greater portion of the propodite. It arises from the ventral and anterior walls of the latter, and is inserted on a very broad tendon which is attached to the ventral side of the dactylopodite (*f. D.*).

#### XI. First walking leg (Pl. III, fig. 22).

**Coxopodite.** There is a posterior extensor and an anterior flexor.

The *extensor* is situated in the fifth pleural muscle chamber. It passes downward, and is inserted on a long narrow tendon immediately behind the dorsal hinge (*ex. C.*).

The *flexor* is a large muscle situated in the anterior and upper portions of the fifth sternal muscle chamber. Its origin is partly on the anterior wall of the chamber and partly on the median plate. It passes outward and downward, and is inserted on a broad tendon on the anterior portion of the coxopodite (*f. C.*).

**Basi-ischiopodite.** There is one dorsal extensor and one ventral flexor muscle.

The *extensor* occupies the dorsal and posterior portion



of the fifth sternal muscle chamber. It arises from the anterior face of the fifth thoracic endosternite, and passes outward and downward, and is inserted on a long tendon on the dorsal side of the basi-ischium (*ex. B.*).

The *flexor* lies in the ventral and posterior part of the fifth sternal muscle chamber. It arises from the median plate, and passes downward and outward. Its insertion is on a fairly broad tendon on the ventral side of the joint (*f. B.*).

In addition to the above flexor there is a small accessory flexor muscle on each side of the former. They are probably comparable to the anterior flexor and lesser posterior flexor of the corresponding segment of the chela.

The muscles of the other segments of this limb are very similar to those described above in the chela. The two muscles of the dactylopodite, however, are extremely small, and almost equal in size.

## XII. Second walking leg.

The muscles here are similar to those of the first walking leg.

**Coxopodite.** The *extensor* arises from the sixth pleural muscle chamber. The *flexor* arises from the sixth sternal muscle chamber.

In the **Basi-ischiopodite** both muscles arise from the sixth sternal muscle chamber.

## XIII. Third walking leg.

The muscles are similar to those of the two previous appendages.

**Coxopodite.** The *extensor* arises from the seventh pleural muscle chamber. The *flexor* arises from the seventh sternal muscle chamber.

In the **Basi-ischiopodite** both muscles arise from the seventh sternal muscle chamber.

## XIV. Fourth walking leg (Pl. III, fig. 23).

In the coxopodite and basi-ischium there are the same muscles as in the other walking legs. There is, however, an additional extensor of the coxopodite. This *ventral extensor* is inserted on a small narrow tendon (*v. ex. C.*) immediately below the insertion of the dorsal extensor.

The muscle chamber in this somite is not divided into pleural and sternal regions. Hence it may be designated the pleuro-sternal muscle chamber (see section on Endophragmal System). All the muscles of the coxa and the basi-ischium arise from this chamber.

The dorsal extensor of the coxopodite arises from the anterior wall of the chamber; the ventral extensor from the median plate; the flexor of the coxopodite from the anterior end of this muscle chamber. The extensor of the basi-ischium arises from the anterior and inner corner of the chamber, and the flexor has its origin on the median plate.

The muscles of the remaining parts of this appendage are similar to those of the other walking legs.

In the chela the coxa swings horizontally. In the first walking leg the coxa is slightly tilted, so that it swings forward and slightly downward. In each of the succeeding walking legs the corresponding part is more tilted, and in the last walking leg the ventral hinge of the coxa is more posterior and the dorsal hinge anterior. So that, instead of swinging horizontally as in the chela, the coxa swings in a plane inclined at a considerable angle to the vertical, and during the movement of extension the limb is capable of being turned almost on to the dorsal side of the carapace. The presence of the additional extensor muscle undoubtedly aids such a movement.

This freedom of movement is probably not of much

value in Cancer. In the swimming crabs, however, where the last thoracic appendages are flattened and oar-like and are utilised as an effective rowing organ, such an arrangement is of no mean importance.

**Muscles of the fore-gut.** These are described in the section on the Alimentary Canal.

The Dorso-ventral muscles are described in the section on Respiration.

It is of interest to note in passing that in the case of those muscles arising from the carapace, there are definite marks on the outside of the shell corresponding in shape and size to the areas of the origin of these muscles. It has been stated above (section on Integument) that the muscle is not directly attached to the chitinous exoskeleton, but arises from the basement membrane underlying the epidermis. How, then, can the marks of the muscle attachments be duplicated on the outer side of the exoskeleton?

The most probable explanation is that in those regions where the muscles are attached to the basement membrane the cells of the epidermis are in some way affected by the underlying muscles. In this manner the rate of secretion of the integument may have been slightly reduced in these localised areas, thus producing the marks on the outer side of the carapace.

#### MUSCLES OF THE ABDOMEN.

On account of the third, fourth and fifth somites being fused together, the abdominal muscles of the male abdomen differ from those of the female.

**Female abdomen** (Pl. IV, figs. 32, 33).

There are two sets of muscles working each somite,

a pair of dorsal extensors, and a pair of ventral flexor muscles.

**Somite I.** Each *extensor* (*ex.* 1) arises as a broad band of muscle from the top of the epimeral region of the last two thoracic somites. It passes inward and backward, and is inserted on the side of the anterior triangular portion of the tergum of the first somite.

Each *flexor* (*f.* 1) muscle arises from the "sella turcica" in the thorax, and passes backward near the median line. It is inserted on a small ingrowth of the sternum immediately in front of the arthrodial membrane separating the first sternum from the second.

**Somite II.** Each *extensor* (*ex.* 2) is inserted on a small concavity in the tergal region of the first somite. It passes backward, and is inserted near the middle line on a tendon which is attached to the anterior extremity of the second somite.

Each *flexor* (*f.* 2) arises from the posterior face of the ingrowth, or tendon, at the posterior end of the first sternum. It passes backward near the median line, and is inserted on the anterior face of a similar tendon at the posterior extremity of the second sternum.

**Somite III.-VI. and Telson.** The muscles in the succeeding abdominal somites have the same arrangement as those of the second somite. The flexor of the last abdominal somite is not inserted on a well-marked tendon. The same applies to both the origin and insertion of the flexor muscle of the telson.

Uropod of female (Pl. IV, fig. 25).

In their natural position the uropods are extended and lie almost horizontal, with their distal extremities pointing toward the posterior end of the abdomen.

The **Protopodite** is capable of two kinds of movement. First there is a movement in an antero-posterior



plane. The flexor muscle, which has very little power, moves the protopodite forward, and the extensor acts in the opposite direction.

The *extensor* (*ex. prot.*) arises from the posterior region of the tergum of the somite to which the uropod belongs. It passes forward and downward, and is inserted on a small tendon on the anterior wall of the protopodite, some distance below the proximal border of the latter.

The *flexor* (*f. prot.*) arises from the anterior region of the tergum. It passes downward and inward, and its insertion is on a tendon arising from the outer border of the protopodite.

The protopodite also has a slight movement from side to side. The flexor muscle draws the appendage toward the middle line and the extensor pulls it outward.

The *lateral extensor* (*l. ex. prot.*) arises from the outer region of the tergum, and passes downward and inward. Its insertion is on a tendon arising from the outer border of the protopodite.

The *lateral flexor* (*l. f. prot.*) arises from the inner part of the tergum. It passes downward and outward, and is inserted on a tendon arising from the inner border of the protopodite.

**Exopodite.** The movement of the exopodite is lateral. There is one extensor and two flexors.

The *extensor* (*ext. ex.*) arises from the outer edge of the protopodite. It passes downward, and is inserted on the inner wall of the exopodite some distance below the arthrodial membrane.

The *flexors* (*d. f. ex., v. f. ex.*) arise from the inner wall of the protopodite. They pass outward, and converge to a single insertion on the inner edge of the exopodite.

The **endopodite** is fused to the protopodite, and has no muscles.

**Male abdomen.**

There are no extensors between the third and fourth somites, and also between the fourth and fifth somites.

According to Williamson, there are only two long flexors at each side arising from the thorax. One is inserted on the sternum of the united third, fourth and fifth somites, and the other is inserted on the telson.

**Uropods of Male.** These muscles have been described by Williamson.\* In the first appendage the endopodite has a strong flexor muscle. The extensor is extremely small, and probably the flexion is effected by the elasticity of the arthrodial membrane. The protopodite has two small muscles, one of which flexes and the other rotates the limb. In the second appendage there is also a strong flexor in the endopodite. The protopodite has a system of small muscles which rotate, extend and flex the appendage.

**Histology of Muscle.**

The muscles of Cancer are composed of striated fibres. Each fibre is an elongated multi-nuclear cell which reveals, in longitudinal sections and in stained preparations, two kinds of striations—longitudinal and transverse. As a rule, the cross striations are the more obvious, and produce the “striped” appearance so characteristic of Arthropod muscle fibres.

Each fibre is composed of numerous longitudinal fibrils, which give rise to the longitudinal striations. In a transverse section across a fibre it is seen that the fibrils have an unequal distribution, and are usually grouped together into polyhedral areas (Cohnheim's areas). The bundle of fibrils constituting a single area is known as a *muscle column*. The various muscle columns are separated

\* Williamson, H. C. *Twenty-second Annual Report of the Fishery Board for Scotland*, p. 104.

from one another by the sarcoplasm (protoplasm), which varies in quantity in different kinds of fibres.

In stained preparations the muscle fibre reveals alternate light and dark cross-striations. At its centre, each light band is interrupted by a transverse line (Krause's membrane). There is also a transverse line stretching across the middle of the dark band (Hensen's line). The latter is only seen with difficulty. Each portion of a fibril between two adjacent Krause's membranes is known as a "sarcomere."

Haycraft's\* experiments led him to believe that the cross striations are due to regularly-occurring varicosities, and some of the preparations made in the course of the present work appear to show this. It is doubtful whether this structure (even if admitted) is alone sufficient to account for the fact that the cross-striations seen in fresh tissue are accentuated under the action of various staining reagents. It is highly probable, as suggested by Schäfer, that the cross striation of the fibrils is due to the heterogeneous nature of the latter.

An examination of the fresh muscles of a crab reveals the interesting fact that—as in the vertebrates—some of the muscles are of a darker colour than others. Sections across the muscle fibres show that, generally speaking, the "dark" muscles have much more sarcoplasm than the "light" ones. Hence Knoll distinguished between *plasmic* (dark) and *aplasmic* (light) fibres. Biedermann† has shown that there is a definite relationship between the amount of sarcoplasm present in a fibre and the nature of the work performed by the fibre. He has, furthermore, stated that "the elements of those muscles which serve

\* Haycraft, J. B. "Cause of Striation of Voluntary Muscular Tissue," *Q.J.M.S.*, Vol. XXI (1881).

† Biedermann, W. *Electro-physiology*, Vol. I.

the most persistent or most strenuous action are richest in sarcoplasm."

In Cancer the muscles present all grades of colour, from an opaque yellowish brown (muscles of scaphognathite) to a transparent white (muscles of appendages). Undoubtedly, the most active muscles of the body are those of the scaphognathite, and probably the flexors and extensors of the abdomen are the most sluggish (in the *Macrura* the abdominal muscles are very strenuous). I append a list of muscles, commencing with the most strenuous and darkest in colour and finishing with the least active. In all cases the position of a muscle on the list for colour agrees with its position regarding its activity.

1. Muscles of the scaphognathite.
2. Muscles of the heart.
3. Mandibular muscles.
4. Anterior cardiac muscles.
5. Extensor muscles of flagella of maxillipedes.
6. Gastric muscles (other than the anterior cardiae).
7. Muscles of the appendages.
8. Extensor and flexor muscles of the abdomen.

### COELOM AND BODY CAVITY.

Arthropods in general are characterised by the presence of a greatly reduced coelom in the adult. This reduction of the coelom is the result of the increase in the blood-holding spaces or sinuses. This system of swollen sinuses, which contain the venous blood, has produced a series of cavities lying between the various organs of the body, and has been termed by Lankester a *haemocoel*. The theory of Phleboedesis formulated by Lankester to account for the development of the haemocoel is as follows:—



"The system of blood-containing spaces pervading the body in Mollusca and Arthropoda is not, as sometimes supposed, equivalent to the coelom or perivisceral space of such animals as the Chaetopoda and the Vertebrata, but is in reality a distended and irregularly swollen vascular system—the equivalent of the blood-vascular system of Chaetopoda and Vertebrata."<sup>2</sup>\*

In Cancer the only remnants of the true coelom are the gonadial sacs and the end sacs of the antennary glands. The labyrinth and bladder of the excretory system are lined by cells derived from epiblast.

## ALIMENTARY CANAL

(Pls. V, VI, VII).

The alimentary canal extends from the *mouth*, which is situated on the ventral side of the cephalic region between the mandibles, to the *anus* on the ventral side of the telson. The nature of the development of the alimentary canal suggests a natural division into three parts:—(1) The *fore-gut*, which is the embryonic stomodaeum, (2) the *mid-gut*, the archenteron of the embryo, and (3) the *hind-gut*, which is the embryonic proctodaeum.

### F o r e - g u t .

The fore-gut commences at the mouth and is formed of the embryonic epiblast. It is lined throughout by a cuticle which is continuous with the exoskeleton around the mouth. The mouth leads into a short *oesophagus* (Pl. VI, fig. 40, *oe.*) which opens into the so-called "stomach," which is continuous behind with the mid-gut.

The mouth is situated on the ventral surface of the

\* Lankester, E. Ray. "The Enterocoela and the Coelomocoela,"  
*A Treatise on Zoology*, Part II.

cephalic region, and is bounded in front by a fleshy lobe—the *labrum* (Pl. III, figs. 18, 20, *lab.*) or anterior lip—and behind by the *metastoma* (*met.*) or posterior lip. On each side of the mouth are the mandibles.

Both the labrum and metastoma have closely packed glands which have the appearance and structure of the “salivary glands” found in the walls of the oesophagus. It is not inconceivable that they have the same function as the oesophageal glands. The mandibles also have at their base a mass of glands which are continuous with those in the ventral portion of the oesophageal walls.

In the **oesophagus** (Pl. V, fig. 35) the epidermal cells (*ch. ep.*) are of great length. In a soft crab with a carapace 25 mm. in width these cells are 90  $\mu$  in length and only 3  $\mu$  wide. On the outer side of the epidermis is a thin chitinous layer about 8  $\mu$  in width. This consists of two layers—a thin outer structureless layer, the cuticle, and a broader inner layer showing evidences of longitudinal striations. On the inner side of the epidermis is a well-marked basement membrane. Below the basement membrane is a layer of connective tissue (*der.*) about 370  $\mu$  in width. This is composed of a dense reticulate mass formed of intercrossing connective tissue fibres. There are also small connective tissue cells scattered about. Embedded in the connective tissue are numerous glands which may conceivably be salivary glands, but which I designate the *oesophageal glands* (*sal. g.*).

On the outer side of the connective tissue of the oesophagus is a layer of circular muscles—the *constrictors of the oesophagus* (*c. oe.*)—and passing through the connective tissue and attached to the basement membrane are numerous muscle bundles—the *dilators of the oesophagus* (*oe. l.*).

Each oesophageal gland is globular and consists of

numerous large conical cells, the apex of each cell pointing to the centre of the mass. Each cell has a well-defined nucleus near its outer side. In the centre of each gland mass is a small cavity into which the secretion from the individual cells is poured. This small central cavity is connected with the lumen of the oesophagus by means of a long narrow duct which passes between the cells of the epidermis. The duct and its walls is probably formed of a single cell, in which case the gland duct is intracellular. These glands are scattered through the connective tissue of the oesophageal wall. They take the stain distinctly, and have a diameter of  $25\ \mu$  to  $35\ \mu$  in the small crab mentioned above. From the above description it would appear that the oesophageal glands are merely modified cutaneous glands.

At the extreme ventral end of the oesophageal wall at each side there is an additional mass of such glands which are very closely packed together (*v. oe. g.*). As mentioned above, these glands are continuous with those of the mandible.

The large and spacious region of the fore-gut which follows the oesophagus is generally termed the "stomach,"\* and is divided into a large anterior portion—the *cardiac chamber* (*card.*)—and a smaller posterior portion—the *pyloric chamber* (*pyl.*).

The **Cardiac fore-gut** (Pl. V, fig. 34, Pl. VI, fig. 40, *card.*) is a large simple sac roughly spherical in shape. The cuticle lining this part of the alimentary canal

\* The term "stomach" is an unsatisfactory one, as this part of the fore-gut is neither embryologically nor physiologically what is generally recognised as a stomach. Also the terms "cardiac" and "pyloric" have no meaning when applied to the Malacostraca, seeing that the cardiac region—as pointed out by Huxley—is the farthest from the heart. It would be inconvenient, however, to reject the terms "cardiac" and "pyloric," as such a change would also involve an alteration in the names of numerous ossicles and muscles connected with the fore-gut. The terms "cardiac fore-gut" and "pyloric fore-gut" will be used in the present Memoir.

presents numerous thickenings to form an elaborate system of plates and teeth known as the "Gastric Mill." This will be described below.

The posterior wall of the cardiac fore-gut is invaginated on its ventral surface to form the *cardio-pyloric valve* separating the cardiac region from the pyloric region.

The **Pyloric fore-gut** (Pl. V, figs. 34, 36) presents a very complicated arrangement.

In the posterior two-thirds of the pyloric region the chitin of the ventral wall is thickened at each side to form the *pyloric ampullae* (*amp.*). These are clearly seen from the outside as swellings on the floor of the pyloric region. The ampullae have their chitinous lining thrown into well-defined longitudinal parallel ridges. From the summits of the ridges there are numerous fine setae projecting into the cavity of the pyloric chamber. Each seta has numerous small hook-like branches. The two ampullae meet in the mid-ventral line in a well-defined ridge—the *inter-ampullary fold* (Pl. V, fig. 36, *i. a. f.*).

The ventro-lateral walls immediately above the ampullae have the chitin enormously thickened at each side to form cushion-like pads projecting into the cavity of the pyloric chamber immediately above the ampullae. These are the *supra-ampullary ridges* ["*voûte ampullaire*," Mocquard] (*amp. c.*). Each cushion has a convex surface which faces inwards and downwards, and the upper parts almost meet in the middle line. The presence of the supra-ampullary ridges and the inter-ampullary fold causes the cavity and the ventral part of the pyloric chamber to be reduced to a narrow two-rayed fissure. The supra-ampullary ridges are covered with numerous fine setae, which stretch across the narrow lumen of this



portion of the pyloric chamber, so as to form—as Huxley suggested—a very effective filtering apparatus.

The dorsal part of the pyloric chamber has a comparatively large cavity. In transverse sections through the pyloric region the lateral walls of the dorsal portion are roughly at right angles to one another.

The supra-ampullary wall (fig. 36, *s. amp.*) is immediately above the supra-ampullary ridges, and is almost horizontal, thus forming the floor of the upper region.

The pleuro-pyloric wall (*pp.*) is on the outer side of the supra-ampullary wall and turns upwards almost at right angles to the latter. This portion of the wall may be complicated by the presence of folds (*up. f.*).

The dorsal wall is simple in structure.

Thus in the posterior two-thirds of the pyloric region the lumen is divided into a wide dorsal portion and a narrow ventral portion, the two parts being capable of complete separation by the concrescence of the inner portions of the supra-ampullary ridges.

The anterior third of the pyloric region is comparatively simple, and shows no such division into dorsal and ventral portions.

It is probable that in the anterior part of the pyloric region the contents undergo a certain amount of separation. For instance, any hard shell-like structures belonging to the creatures taken in as food will be separated from the soft and nutritious parts. The hard parts pass backwards along the wide dorsal chamber, and by means of an elaborate system of valves they are carried directly into the hind-gut without coming into contact with the unprotected walls of the mid-gut (fig. 40, *val.*). The valves are flap-like structures projecting backwards from the upper side of the posterior end of the fore-gut.

As suggested by Huxley and Mocquard the function of these valves may be partly to prevent the waste matter from passing back into the fore-gut, but Cuénot has claimed that the valves are also used, as described above, for carrying the hard waste pieces directly into the hind-gut. The mid-gut is not lined with chitin, and consequently the sharp pieces present amongst the food in the alimentary canal would be liable to tear the walls of the mid-gut.

The soft parts of the aliments are passed through the narrow ventral portion of the pyloric region, where they are sieved by the setae stretching across the lumen, and near the posterior region of this region the food comes into contact with the secretion from the digestive glands. The latter open into the ventro-lateral wall of the mid-gut immediately behind the ampullae, and the digestive fluid flows forward and mixes with the food in the ventral part of the pyloric region.

In the cardiac and pyloric regions we have essentially the same histological arrangements as in the oesophagus. The epidermis consists of columnar epithelium of much less length than the cells of the oesophageal epidermis. The chitinous layer is very thin except in the regions of the ossicles of the gastric mill, which are merely thick portions of the chitin which have become strongly calcified. The basement membrane is well marked and the connective tissue is a very thin layer. Embedded in this layer are very thin bands of circular and longitudinal muscles.

Mid-gut (or Mesenteron) (Pl. V, fig. 34, *m. g.*).

The mid-gut is an extremely short portion of the alimentary canal, being only about 10 mm. long in a full-grown crab. This is the only part of the alimentary

canal which is derived from the archenteron and is lined by cells formed from the hypoblast.

From the mesenteron arise a pair of caeca—the so-called “pyloric caeca.” This is an unfortunate designation, as they do not arise from the pyloric region of the fore-gut. I therefore propose to substitute the name of **Mid-gut caeca** (fig. 34, *caec.*). Each caecum arises from the side of the anterior part of the mid-gut. It passes forward as a narrow tube alongside the pyloric chamber, and is closely applied to the postero-lateral region of the cardiac chamber of the fore-gut. On a level with the widest part of the latter the caecum terminates in a much convoluted portion.

The digestive glands (fig. 34, *di. gl.*) arise at each side from the ventro-lateral region of the mid-gut, immediately behind the origin of the mid-gut caeca. These will be described more fully below.

The epithelium lining the mid-gut (Pl. X, fig. 61) consists of columnar cells having a length of  $55\ \mu$  in an adult crab. There is no cuticular lining to the epithelium of this region, but each cell has an outer striated border from  $1\ \mu$  to  $2\ \mu$  in thickness. This is similar to the “Härchensaum” present in the mid-gut of *Anurida*\* and in the duodenum of many vertebrates. It is very probable that this striated border is characteristic of the mid-gut epithelium of arthropods in general, and probably the thin cuticle lining the mid-gut of *Ligia* described by Hewitt† is a similar structure.

In many of the epithelial cells are refractive bodies, probably the fat globules mentioned by Cuénot. Beneath the epithelium is a thick basement membrane. In the comparatively broad layer of connective tissue beneath the basement membrane are thin layers of circular and longitudinal muscles.

\* Imms. *L.M.B.C. Memoir*, “*Anurida*.”

† Hewitt. *L.M.B.C. Memoir*, “*Ligia*.”

H i n d - g u t (Pl. V, fig. 34, *h. g.*)

The hind-gut or intestine is a long narrow tube extending from the posterior end of the mid-gut to the anus which opens on the ventral surface of the telson. Near to the mid-gut it passes below the median bridge-like portion of the reproductive organs; passing further back it runs beneath the pericardium, and a short distance behind the latter it enters the abdomen, along which it pursues a straight course. Just before entering the abdomen the hind-gut gives off from its right side a long coiled tube—the **hind-gut caecum** (fig. 34, *i. caec.*).

The caecum lies above the hind-gut, and the coils, which are packed very closely together, extend into the first segment of the abdomen.

The hind-gut has very pronounced columnar epithelium (Pl. X, fig. 62). This is lined by a thin chitinous layer, consisting—as in the fore-gut—of an outer cuticle, and a layer longitudinally striated which appears to be continuous at the anus with the pigment layer of the exoskeleton. The epithelium rests upon a basement membrane outside of which are thin layers of circular and longitudinal muscles.

In the walls of the hind-gut immediately behind the mid-gut there are closely packed glands very similar in structure to those present in the walls of the oesophagus.

There are also glands, having a similar structure to the above, present in the walls of the hind-gut in the abdominal region. They are not closely packed (fig. 62).

## DIGESTIVE GLAND.

The digestive gland (“liver,” “hepato-pancreas”) (Pl. V, figs. 34, 37, 38, 39) is a large yellowish-brown\*

\* This colour is due to lipochrome. (Miss Newbigin, *Journ. Physiol.*, Vol. XXI., p. 237, 1897.)



organ occupying nearly the whole of the ventral side of the anterior region of the cephalothorax. It is a lobulated structure composed of a large number of digitate tubular outgrowths, and arises from the mid-gut at each side. The front edge of the gland sweeps backward close to the antero-lateral border of the carapace and resembles the latter in having a notched edge. The posterior border of the gland is generally on a level with the anterior region of the branchial chamber: in other words, the branchial chamber is only covered by the digestive gland at its anterior end. Posteriorly the gland occupies the ventral part of the region between the muscles of the thoracic walking legs, and below the pericardium and hind-gut. Throughout the digestive gland is covered by the gonads (Pl. VIII, fig. 51). The gland does not extend into the abdomen.

Arising from the mid-gut at each side there are three main ducts which communicate with smaller ducts. These branch repeatedly, and ultimately end in the cavities of the tubules of which the main part of the gland is composed. Thus the tubules have a cavity which is continuous with that of the mid-gut, and both the ducts and the tubules are lined by cells derived from the embryonic hypoblast. Each of the main ducts mentioned above receives the digestive ferments from one of the three main lobes into which each half of the gland is divided. These lobes are as follows (fig. 34):—(1) An antero-lateral lobe having its outer border marked by notches which correspond to the markings of the antero-lateral border of the carapace; (2) a postero-lateral lobe lying above the anterior part of the branchial chamber; and (3) a posterior lobe which lies between the muscles of the thoracic walking legs.

## Histology of the Digestive Gland

(Pl. V, figs. 37, 38, 39).

In sections the tubules are seen to be closely packed together, generally being separated only by a very thin layer of connective tissue (fig. 37, *c. t.*) or a small blood sinus. Sometimes, however, the walls of the tubules are not separated from each other by any tissue. The lumen of the tubules has four angles in transverse section, and the cells at the angles are much shorter than the others.

The *ducts* are lined by a single layer of large columnar and non-glandular cells. In the sections stained with methyl-blue eosin these cells take the stain more readily than the cells of the tubules.

The *tubules* (fig. 37) have three kinds of cells.

(1) **Fat cells** (fig. 37, *f. c.*, fig. 38). These are columnar cells from  $70\ \mu$  to  $120\ \mu$  in length and  $15\ \mu$  wide. The contents of the cells are vacuolated, due to the presence of fat globules (fig. 38, *g. f.*). The border of each cell in contact with the lumen of the tubule is striated (*sb.*). The nucleus (*n.*) is generally situated in the inner portion of the cell.

(2) **Ferment cells** (fig. 37, *fm. c.*, fig. 39). These are not quite as long as the fat cells, but they are about four times as broad. Each cell contains a large globular mass (fig. 39, *f. v.*) which nearly fills the whole cell. These masses are yellowish-brown and are responsible for the characteristic colour of the digestive gland. According to Frenzel each mass is enclosed in a bladder, and the vesicles are more abundant during feeding time than during the fasting periods. On the side of the cell in contact with the lumen of the tubule there is a small amount of vacuolated protoplasm which exhibits striation. The border of the cell in contact with the lumen was

described by MacMunn as being ciliated. This is highly improbable, and it is more likely that we have in both the ferment cells and the fat cells a striated hem (Härchensaum) (*sb.*) similar to that already described in the mid-gut epithelium. The nucleus is situated in that portion of the cell farthest removed from the lumen.

(3) **Young cells** (fig. 37, *y. c.*). These are small cells found between the larger cells near the periphery of the tubules. These young cells stain deeply and will eventually give rise to the fat cells or ferment cells.

### Physiology of the Digestive Gland.

As pointed out by Cuénot, the digestive gland has many functions, which may be summarised as Digestion, Absorption, Excretion, Elimination and Regulation.

**Digestive function.** According to MacMunn, Frenzel and others the gland is a pancreas, and the ferments produced (proteolytic and amylolytic) are poured into the ducts of the gland and thence into the mid-gut. The ferments are produced entirely in the ferment cells.

The fat cells have the power of forming and storing fat.

Roaf\* found that the action of the extract of the digestive gland was as follows:—

It does not digest coagulated white of egg. It digests fibrin most actively in alkaline solution, but not actively in acid solution. It converts starch into sugar, and inverts cane sugar. It does not hydrolise olive oil, but it hydrolises methyl acetate.

**Function of absorption.** According to Cuénot the digestive gland is of great importance as an accessory organ for absorbing the products of digestion. The

\* Roaf, H. E. "A Contribution to the Study of the Digestive Gland in Mollusca and Decapod Crustacea." *Bio-Chemical Journal*, Vol. I, Nos. 8 and 9.

mid-gut is the only portion of the alimentary canal not lined with chitin, and therefore the absorption of the soluble products of digestion can only take place in this region. It is inconceivable that the short mid-gut, even with the mid-gut caeca, can be the *only* region where the process of absorption is carried on. The digestive gland, which is merely an outgrowth from the mid-gut, is richly supplied with blood, and it is an easy matter for the fluids to pass from the mid-gut into the tubules and through the cells into the blood stream. Thus the digestive gland becomes an accessory absorptive organ of no mean importance.

**Excretory function.** It was observed by Cuénot and MacMunn that when a Crustacean was injected with certain colouring matters, the latter were discovered in the ferment cells of the digestive gland as well as in the cells of the recognised excretory organ. Cuénot is of the opinion that the pigment contained in the excretory cells is of an excretory nature, and that when the contents of these cells ultimately find their way into the alimentary canal, the excretory pigment becomes separated from the ferments and passes down the hind-gut to the exterior.

**Function of elimination.** During the process of absorption, Cuénot states that the cells of the digestive gland keep back many useless products which are afterwards carried to the exterior together with the excretory products. This is quite distinct from the excretory function.

**Function of regulation.** In addition to the other functions it is probable that the digestive gland is capable of regulating the composition of the blood, especially with regard to the quantity of water contained in the blood.

**S u m m a r y.** As the food enters in at the mouth it will come into contact with the secretion from the



oesophageal glands. In the cardiac region of the fore-gut the food is broken up in a very effective manner. Passing back into the pyloric chamber, the food encounters the cardio-pyloric valve. Here the large pieces are prevented from passing into the pyloric chamber. The food which passes into the latter chamber probably undergoes a further process of sifting, the useless material passing along the dorsal portion of the pyloric chamber and the food being passed along the ventral portion. In this ventral region the food first comes into contact with the digestive ferments. Both are well mixed by the action of the muscles of the pyloric chamber.

As already stated, the probable regions of absorption are the mid-gut, mid-gut caeca and the tubules of the digestive gland. The waste products pass down the long hind-gut to the exterior.

#### OSSICLES OF THE FORE-GUT.

(Pl. VI, figs. 40, 41, 43, 44.)

In certain regions of the fore-gut the chitinous lining is thickened and strongly calcified to form *ossicles*. These ossicles give attachment to muscles. One set of ossicles in the dorsal and lateral walls of the cardiac region are connected with three tooth-bearing ossicles. This system of plates which is worked by the anterior and posterior gastric muscles (see section on Muscles of the Fore-gut) forms a very effective apparatus for breaking up the food which has passed into the cardiac fore-gut. Hence the name *gastric mill*.

In addition to the ossicles of the gastric mill there are "supporting ossicles" in both the cardiac and pyloric regions. To these supporting ossicles are attached the various muscles of the fore-gut.

### Ossicles of the Gastric Mill.

The **Mesocardiac Ossicle** (*m.c.*) is a small median ossicle in the dorsal wall of the cardiac region. It is triangular in shape, with the apex pointing forwards. It is not clearly separated from the urocardiac ossicle which passes posteriorly, and it is only partially separated from the pterocardiac ossicle which extends laterally. The ossicle is thicker dorso-ventrally at its posterior end, and to the thickened posterior edge the anterior ends of the cardio-pyloric muscles are attached. In the *Macrura* and the *Anomura* the mesocardiac ossicle is much larger than in the *Brachyura*, and the pterocardiac pieces are much smaller.

One pair of **Pterocardiac Ossicles** (*pt.c.*). They are situated to the right and left of the mesocardiac piece and in contact with it. The posterior border is almost straight, and the anterior border is curved. Each ossicle is broadest on its inner side, and tapers towards its outer extremity. Near the inner border of each ossicle is a smooth area where the anterior gastric muscle is inserted. Each ossicle extends outwards, and its outer extremity articulates with the zygocardiac ossicle by means of the *antero-lateral ligament* (*lig.*).

One pair of **Zygocardiac Ossicles** (*z.c.*) lying in the supero-lateral wall of the cardiac region of the fore-gut. Each passes backwards and inwards, and comes into contact at its posterior end with the exopyloric ossicle, thus forming a connecting link between the ossicle of the cardiac and the pyloric regions. The zygocardiac ossicle is irregular in shape. The anterior part is rod-like, but the ossicle becomes gradually broader as it passes backwards, and the posterior portion is a broad rectangular plate which bears the lateral tooth. One side

of the ossicle points inwards, and the other faces outwards. The inner face is concave and the outer face is convex. The inner edge of the ossicle folds outwards so as to produce a deep groove on the outer side below the convexity. The ossicle has four borders. The *anterior border* is concave and terminates at its posterior extremity in the large anterior tooth. The *dorsal border*, which can be seen through the dorsal wall of the stomach, is also concave. It passes backwards and inwards and ends at the posterior border. The *posterior border* has a large indentation into which the anterior border of the exopyloric ossicle fits. The *inner border* lies obliquely, being nearer the middle line at its anterior end. The ossicle appears to be much thicker at its inner border than in any other region. This thickness is not real, but is merely due to the ossicle folding outwards at its inner border. This inner border bears the *denticles*. Anteriorly there is a large single denticle, which is followed by about seven smaller denticles, which point inwards and decrease in size from before backwards. The folded edge of the inner border is crossed by about twenty-four transverse ridges. This system of denticles and ridges on the zygocardiac ossicle is known as the **lateral tooth** (*lat. t.*).

The **Exopyloric Ossicles** (*ex. py.*) are a pair of small triangular plates, each of which lies between the posterior border of the zygocardiac ossicle and the pyloric ossicle. The superior border gives support to the posterior end of the outer part of the cardio-pyloric muscle, and on its external face it provides insertion for the external part of the posterior gastric muscle.

The **Urocardiac Ossicle** (*u.c.*) is a median plate more or less fused with the mesocardiac ossicle in front. It passes backwards and downwards as a broad, thin rectangular plate. At its posterior end, which articulates

with the propyloric ossicle, it bears the large blunt **median tooth** (*med. t.*) on its ventral surface.

The **Propyloric Ossicle** (*pr.p.*) is a small median plate situated almost vertically. When the gastric mill is at rest the lower end of this ossicle is considerably behind its upper end. Its upper end articulates with the front portion of the pyloric ossicle, and its lower end is in contact with the posterior end of the urocardiac ossicle. The plate is roughly triangular in shape and its apex, which points downwards, is bifurcated. The base of the triangle is dorsal and is extremely concave. The ossicle is highly calcified around the edges, but in the centre it is almost membranous.

The **Pyloric Ossicle** (*o.py.*) is a median ossicle lying between the two exopyloric ossicles which articulate with it at each side. It covers the anterior part of the pyloric region of the stomach. Its central portion is membranous, but laterally it is slightly calcified. These lateral calcifications indicate that the pyloric ossicle is really a paired structure. In the *Macrura* all signs of the double origin disappear.

#### Cardiac "Supporting Ossicles."

The **Pectineal Ossicles** (*pec.*) are a pair of irregular hammer-shaped ossicles, each lying in the lateral wall of the fore-gut beneath the posterior portion of the zygocardiac ossicle. The curved "handle" of the hammer points anteriorly. On the inner side of the "head" of the hammer are three claw-like teeth. These are the **lateral accessory teeth** (*a.t.l.*). ["Infero-lateral cardiac teeth," Huxley.]

The **Prepectineal Ossicles** (*p.pec.*) are a pair of long narrow rod-like ossicles, each being concave on its inner border and extending upwards from the pectineal ossicle



to the outer edge of the zygo-cardiac ossicle with which it articulates by means of a ligament.

One pair of **Post-pectineal Ossicles** (*pt. pec.*) Each is a narrow rod-like ossicle which passes backwards from the pectineal ossicle to the posterior wall of the stomach. It then suddenly turns downwards and runs down the posterior wall of the cardiac fore-gut as a straight rod. At its lower end the ossicle turns forwards for a short distance. On the internal border of the ossicle there is a row of setae projecting into the stomach.

The **Infero-lateral Cardiac Ossicles** (*i.l.*) are a pair of long rod-like ossicles, each of which lies immediately behind and parallel to the rod-like portion of the post-pectineal ossicle. Dorsally the ossicle is in contact with the sub-dentary ossicle, and ventrally it terminates on a level with the lower end of the post-pectineal ossicle. The ossicle is broader at its upper end and tapers gradually towards its lower extremity.

There is one pair of **Sub-dentary Ossicles** (*s.dt.*) At its anterior end each ossicle is in contact with the inner border of the zygo-cardiac ossicle. The ossicle passes downwards and backwards as a somewhat curved rod, and its posterior end touches the upper end of the infero-lateral cardiac ossicle.

The **Lateral Cardio-pyloric Ossicles** are a pair of small ossicles articulating with the posterior and upper end of the infero-lateral cardiac ossicles.

**Postero-lateral Cardiac Plates** (*cd. pl.*). These are a pair of broad plates roughly quadrangular in shape, each lying in front of the post-pectineal ossicle. It is a membranous area having no decided calcification, but being distinctly thicker than the ordinary wall of the stomach. There are two rows of long setae arranged along the posterior edge of each plate and projecting into the cavity of the stomach.

The **Antero-lateral Cardiac Plates** (*cd.al.*) are a pair of thickened areas in the side walls of the stomach in front of the postero-lateral cardiac plates, but they are not so well defined as the latter.

The *Cardio-pyloric valve* (*c.p.v.*) is the thickened median portion of the posterior wall of the cardiac fore-gut. Its upper end is invaginated into the floor of the fore-gut so as to form an incomplete partition between the cavities of the cardiac and pyloric regions of the fore-gut. The top of the cardio-pyloric valve is richly clothed with setae.

### Pyloric "Supporting Ossicles."

In the *dorsal wall* of the pyloric fore-gut there are three pairs of ossicles.

The **Anterior Mesopyloric Ossicles** (*a.mes.*) are a pair of small ossicles lying immediately behind the pyloric ossicle near the median dorsal line.

The **Posterior Mesopyloric Ossicles** (*p.mes.*) are a pair of small ossicles lying behind the anterior pair.

The **Uropyloric Ossicles** (*u.py.*) are a pair of small ossicles lying in the roof of the posterior part of the pyloric region and immediately behind the posterior mesopyloric ossicles.

In the *ventral wall* of the pyloric fore-gut the main supporting ossicles are as follows:—

The **Antero-inferior Pyloric Ossicle** (*a.i.p.*) is a median plate shaped somewhat like a truncated triangle. The base of the triangle points forwards and comes into contact with the cardio-pyloric valve. This ossicle lies in front of the inter-ampullary groove.

The **Pre-ampullary Ossicles** are a pair of small plates. Each lies at the side of the antero-inferior pyloric ossicle and immediately in front of the pyloric ampulla.

The **Postero-inferior Pyloric Ossicle** is a median curved rod-like ossicle. It is concave anteriorly, and is situated behind the pyloric ampullae.

In the *lateral walls* of the pyloric fore-gut there are the following principal ossicles:—

On the supra-ampullary walls there are three pairs of ossicles, viz., the **Anterior** (*a.s.a.*), **Middle** (*m.s.a.*), and **Posterior** (*p.s.a.*) **Supra-ampullary Ossicles**.

There are also three pairs of ossicles in the pleuro-pyloric walls, viz., the **Anterior**, **Middle** and **Posterior Pleuropyloric Ossicles**.

The positions of these six pairs of ossicles are indicated by the names.

#### MUSCLES OF THE FORE-GUT. (Pl. VII.)

Mocquard\* has divided the muscles of the fore-gut into two kinds. The *extrinsic muscles* are those muscles which have points of origin on some part of the skeletal system outside the fore-gut, and which are inserted on to ossicles lying in the walls of the fore-gut. The *intrinsic muscles* are attached at both ends to ossicles lying in the walls of the fore-gut.

##### Extrinsic Muscles.

**Anterior Gastric Muscles** (*g.a.*)—one pair. Each muscle has its origin on the procephalic process. Both pass directly backwards near the median line, being only slightly separated from one another, and are inserted on the front of the pterocardiac ossicles near the middle line.

**Inner Posterior Gastric Muscles** (*g.p.i.*)—one pair. They arise from two small calcareous projections, almost median in position, situated on the under side of the mesogastric region of the carapace. Each muscle passes

\* Mocquard, *Annales Sciences Naturelles*, 6 ser., t. 16, 1883, p. 238.

downwards and forwards, and is inserted on the front part of the pyloric ossicle.

**Outer Posterior Gastric Muscles** (*g.p.e.*)—two pairs. The two muscles at each side run together so that they may be mistaken for a single muscle. They arise from the under side of the mesogastric region of the carapace, some distance in front of the origin of the dorsal pyloric dilator muscles, but not so near the middle line. They pass downwards, forwards and inwards, and are inserted on the external face of the exopyloric ossicle.

The above three sets of muscles are concerned in the working of the gastric mill. In addition to these the intrinsic muscles—the cardio-pyloric muscles—to be described later, are also used in connection with the gastric mill.

The following muscles serve to dilate the fore-gut:—

**Upper Anterior Dilator Muscles** (*a.s.*)—one pair. Each arises from the inner side of the cephalic sternum immediately behind the orbit. The muscle is not a compact one, but passes backwards, upwards and inwards as a series of muscular strands which gradually diverge. They are inserted on the anterior and outer corner of the fore-gut.

**Lower Anterior Dilator Muscles** (*d.ai.*)—one pair. These are a smaller pair of muscles than the preceding. They are very close to the middle line so as to appear almost as a single median muscle. Each arises on the upper side of the epistoma near the middle line and passes backwards and slightly upwards, being inserted on the lower part of the front wall of the fore-gut near the median line. As in the preceding case, the muscle is composed of several separate strands which diverge as they approach the point of insertion.

**Antero-lateral Dilator Muscles** (*d.la.*)—one pair.



These are narrow muscle bands each arising about half way along the outer edge of the roof of the pre-branchial chamber. Each passes inwards and downwards parallel to the front edge of the carapace and is inserted on the lateral wall of the cardiac region of the fore-gut, above the oesophagus.

**Postero-lateral Dilator Muscles** (*d.lp.*)—one pair. These are broad muscles arising near the point of origin of the preceding muscles. Each passes directly inwards and slightly backwards and downwards. The muscle broadens considerably as it approaches the fore-gut. Its insertion is on the anterior edge of the postero-lateral cardiac plate.

**Dorsal Pyloric Dilator Muscles** (*d.sup.*)—two pairs—anterior and posterior. The two muscles at each side run close together so that it is difficult to distinguish the separate muscles. They arise close together from the under side of the carapace just behind the origin of the outer posterior gastric muscles. They pass downwards and slightly forwards and are inserted on the ossicles of the dorsal wall of the pyloric region of the fore-gut. The anterior muscles are inserted on the posterior mesopyloric ossicles and the posterior muscles on the uropyloric ossicles.

**Ventral Pyloric Dilator Muscles.** Two pairs—outer and inner. Each of the *inner pair* (*i.py.i.*) is a long narrow muscle arising near the base of the mandibular apophysis. It passes upwards and slightly backwards on the inner side of the posterior oesophageal dilator muscle and runs very close to the posterior wall of the cardiac region. It is inserted on the antero-inferior pyloric ossicle in the ventral wall of the pyloric region. Each of the *outer pair* (*i.py.e.*) is much shorter than the inner pair. Its origin is on the endopleurite of the first maxillary

segment. From this the muscle passes upwards and is inserted on the ventral pyloric wall on the outside of the insertion of the inner pair.

The following muscles dilate the oesophagus:—

**Upper Anterior Oesophageal Dilator Muscles** (*oe.as.*)

—one pair. Each of these muscles arises from the epistoma close to the origin of the upper anterior dilator muscle. Passing backwards and slightly upwards below the latter muscle, it is inserted on the anterior wall of the oesophagus. The muscle is not compact, but is made up of separate strands which diverge as they approach their insertion.

**Lower Anterior Oesophageal Dilator Muscles** (*oe.ai.*).

One pair of very small muscles. Each arises from a small eminence on the posterior part of the epistoma near the middle line. These eminences are behind the origin of the previous muscle. The muscle passes backwards below the previous muscle, and its insertion on the anterior wall of the oesophagus is immediately below that of the previous muscle.

**Lateral Oesophageal Dilator Muscles** (*oe.l.*)—one pair.

Each of these muscles is made up of three distinct bands of muscle fibres. Near its origin the muscle is compact, but the fibres diverge as they approach the oesophagus. Each muscle arises near the extreme posterior angle of the epistoma and passes inwards below the upper muscle. Its insertion is on the lateral wall of the oesophagus.

**Posterior Oesophageal Dilator Muscles** (*oe.p.*)—one pair.

Each muscle arises from the top of the pillar-like portion of the endopleurite of the first maxillary segment and passes inwards and downwards. It runs external to the inner ventral pyloric dilator, and crossing over that muscle it is inserted on the posterior wall of the oesophagus.

## Intrinsic muscles.

**Cardio-pyloric Muscles** (*c.py.*) These consist of one median and two lateral muscles. The *median* muscle extends from the thickened posterior border of the mesocardiac ossicle to the upper edge of the propyloric ossicle. The *lateral* muscles extend from the mesocardiac ossicle to the exopyloric ossicle. These muscles are used in connection with the gastric mill and are concerned in bringing the ossicles of the mill back to their original position after each series of complicated movements effected by means of the gastric muscles.

**Lateral Cardiac Muscles** (*c.lat.*)—three pairs. The three muscles at each side may be distinguished as the *upper*, *middle* and *lower* muscles respectively. The *upper muscle* arises from the upper edge of the infero-lateral cardiac ossicle and passes upwards and forwards as a broad sheet of muscle to the dorsal border of the zygocardiac ossicle. The *middle muscle* also arises from the upper edge of the infero-lateral cardiac ossicle below the origin of the upper muscle and passes upwards and forward parallel to this muscle. It is inserted on the prepectineal ossicle, and also on the anterior part of the dorsal border of the zygocardiac ossicle. This muscle is much narrower than the previous one. Both sheets of muscle are broader at their insertion than at their origin. The *lower muscle* is a short broad sheet arising from the side of the infero-lateral cardiac ossicle, and passing across the upper portion of the postero-lateral cardiac plate. Its insertion is on the antero-superior border of this plate. According to Mocquard, these muscles raise the cardio-pyloric valve.

The **Postero-inferior Cardiac Muscle** (Fig. 48, *c.i.*). This is a median broad sheet of muscle covering the

posterior wall of the cardiac region of the fore-gut. It is attached at each side to the posterior border of the infero-lateral cardiac ossicle.

**Anterior Cardiac Muscle** (*c.ant.*). This is a median muscle extending as a broad and thin sheet down the front wall of the fore-gut. It arises in the median line on the front of the mesocardiac ossicle and passes forwards. As it passes downwards along the front wall of the fore-gut it divides into two main branches, which are attached separately to the front wall of the fore-gut.

The above muscle must not be confused with the muscle of the same name described by Mocquard. The latter muscle is on the antero-lateral wall. I therefore designate it the **Antero-lateral Cardiac Muscle** (*c.al.*). There is one pair of these muscles, each being situated on the antero-lateral wall of the fore-gut immediately above the oesophagus. It is attached to the anterior border of the membranous antero-lateral cardiac plate, and passes upwards almost to the median line.

The above two sets of muscles act as constrictors of the cardiac portion of the fore-gut.

**Circular Oesophageal Muscles** (*c.oe.*). These are present as a broad band running around the oesophagus and acting as constrictors of the oesophagus.

**Lateral Pyloric Muscles** (*py.lat.*). There are several pairs of muscles—some broad and others very small—arising at each side from the upper part of the post-pectineal ossicle and the infero-lateral cardiac ossicle. They pass upwards and are inserted on the various ossicles of the lateral and dorsal walls of the pyloric region of the fore-gut. These muscles serve as constrictors of this region of the fore-gut.



## THE MECHANISM OF THE GASTRIC MILL.

According to Huxley\* the movement of the gastric mill is effected by means of *both* the anterior and posterior gastric muscles. By the contraction of these muscles the urocardiac tooth is thrown forward, and simultaneously the zygocardiac teeth are rotated inwards and the three teeth meet in the middle line.

Mocquard has been fortunate enough to observe the movements in a living *Stenorhyncus* having a remarkably transparent carapace. He states that the active movement is brought about *almost solely* by means of the anterior gastric muscles. If the posterior muscles act at all, it is only very feebly and spasmodically. When the anterior gastric muscles contract, the urocardiac ossicle and the median tooth are thrown forward. The movement is slightly complicated because of the connection between the posterior part of the urocardiac ossicle and the lower part of the propyloric ossicle. When in a state of rest the lower part of the latter ossicle lies considerably behind its upper border. As a result of the contraction of the anterior gastric muscle the lower part is drawn forward so that the ossicle takes up a vertical position. The median urocardiac tooth, if not in contact with the propyloric ossicle, would have a simple backward and forward movement. But the connection between the two ossicles causes the median tooth to move in an arc the convexity of which points downwards.

Since the anterior gastric muscles are inserted on the inner ends of the pterocardiac ossicles, the latter are also drawn forward when the muscles contract. This movement causes the outer ends of the ossicles to turn downwards and inwards. Because of the connection between

\* Huxley, T. H. *The Crayfish*. [International Science Series.]

the pterocardiac and the zygocardiac ossicles the anterior handle-like portion of the latter are also drawn downwards and inwards. Posteriorly the zygocardiac ossicles are in contact with the exopyloric ossicles, which in their turn articulate with the pyloric ossicle. Therefore if we consider the zygocardiac and the exopyloric ossicles as a single rod, we have a lever of the second order, the fulcrum being at the anterior end and the weight in the region of the zygocardiac tooth. Thus, the application of the force at the anterior end rotates the tooth downwards and inwards, and the three sets of teeth meet in the middle line. When the muscles relax the ossicles spring back into their original position, partly because of the elasticity of their joints, but mainly by means of the action of the cardio-pyloric muscles.

## THE BLOOD VASCULAR SYSTEM

(Pl. VII, figs. 49, 50; Pls. VIII, IX).

Briefly stated the scheme of circulation is as follows. The pure blood returning from the gills passes into the Pericardium by means of the Branchio-cardiac veins. From the Pericardium the blood enters the heart through the ostia. From the anterior end of the heart there arise five arteries carrying the blood to the gonads, digestive glands, fore-gut, and the front part of the body. From the posterior region of the heart two median arteries arise which supply the abdomen and the appendages. The impure blood returning from the system does not pass to the gills along definite vessels, but flows through irregular spaces or *sinuses* between the various organs. The blood from the sinuses eventually reaches the gills and passes along the Afferent Branchial Sinuses on the outside of the gills. The blood is distributed to

the various gill lamellae where it is oxygenated. The pure blood leaves the gills by the Efferent Branchial Veins, running along the inside of the gills and which pass into the Branchio-cardiac veins.

The Pericardium (Pl. IX, figs. 54, 56, *Per.*) is a closed cavity surrounding the heart and having thin transparent walls. It is situated immediately beneath the cardiac region of the carapace, and between the "flancs." It lies above the hind-gut and covers the posterior portions of the digestive gland and gonads. When viewed from above the shape of the pericardium is roughly pentagonal (fig. 54). The base of the pentagon is anterior and the apex is posterior.

The Branchio-cardiac veins (Pl. IX, fig. 54, *bc 1-5*) enter each side of the pericardium by means of three wide openings which have no valves. The *first* opening is situated at the anterior corner of the pericardium and receives the first and second branchio-cardiac veins. The *second* opening is situated a little behind the first and receives the third branchio-cardiac vein. The *third* opening is situated at the postero-lateral corner, and at this point the fourth and fifth branchio-cardiac veins enter the pericardium.

The Heart (Pl. VII, figs. 49, 50) is a white semi-transparent body, pentagonal in shape when seen dorsally and having a rectangular shape when viewed from the side. Two angles of the pentagon are anterior and the other three are posterior. The heart is suspended in the pericardium by means of the *alae cordis* (fig. 49, 50, *cd.1-6*), which are bands of fibrous connective tissue stretching across from the angles of the heart to the wall of the pericardium. Each *ala cordis* appears to have a short band of muscle fibres attached to its outer extremity.

The alae cordis are eleven in number (fig. 49, 50).

*Dorsal Antero-lateral* (cd.1)—one pair. Stretching from the dorsal side of each of the antero-lateral corners of the heart to the corresponding corner of the pericardium.

*Ventral Antero-lateral* (cd.2)—one pair. Immediately beneath the dorsal antero-lateral band. Extending from the ventral side of each of the antero-lateral corners of the heart to the corresponding corner of the pericardium.

*Dorsal Postero-lateral* (cd.3)—one pair. Extending from the dorsal side of each of the postero-lateral angles of the heart to the corresponding angle of the pericardium.

*Ventral Postero-lateral* (cd.4)—one pair. Having a similar position to the dorsal postero-lateral band, but lying immediately beneath it.

*Median Posterior* (cd.5)—A single band arising from the dorsal side of the posterior angle of the heart and stretching across to the posterior angle of the pericardium.

*Posterior* (cd.6)—one pair. Arising ventrally from the postero-lateral side of the heart and crossing to the postero-lateral side of the pericardium.

The walls of the heart are also very muscular, and the cavity of the heart is crossed by numerous strands of muscle.

The blood enters the heart from the pericardium by means of the *Ostia*. There are three pairs of ostia—one pair at the anterior end of the dorsal wall of the heart (Figs. 49, 50. *a.ost.*), one pair at the posterior end of the dorsal wall (*p.ost.*), and the third pair are found in the lateral walls of the heart—one ostium at each side (*l.ost.*). Each ostium is valved so as to prevent the blood from returning to the pericardium.



## THE ARTERIES. (Pls. VIII, IX.)

The following arteries are given off from the heart: At the *anterior* end (1) the median *Cephalic artery*, and on each side of this is (2) a *Lateral artery*, and (3) a *Hepatic artery*, all passing forwards. At the *posterior* end there are two median arteries arising about the same point, (4) the *Descending artery* passing downwards, and (5) the *Posterior Aorta* passing backwards above the intestine.

At its origin from the heart each artery is valved, so as to prevent the blood from returning.

**Cephalic artery** [Ophthalmic artery] (Pl. VIII, fig. 51. *o.art.*). This is a median artery arising from the anterior end of the heart. From its origin it passes directly forward above that portion of the gonads situated between the internal adductor muscles of the mandibles. It pursues a straight course over the pyloric and cardiac regions of the stomach and between the anterior gastric muscles. So far the course of the artery has been entirely superficial, but near the anterior end of the cardiac fore-gut it dips downward and divides into two branches immediately above the brain. Each branch passes outward and supplies the eyes and also the various parts of the front region of the head.

**Lateral artery** [Antennary artery] (Pl. VIII, Fig. 51. *a.art.*) There is one pair of lateral arteries, each of which arises from the anterior end of the heart a little outside of the origin of the cephalic artery. On leaving the heart the lateral artery passes outward, making an angle of about  $40^{\circ}$  with the cephalic artery. Almost immediately it passes through the outer portion of the internal adductor muscle of the mandible (*i. a. md.*). It then curves outward, sweeping around the stomach until it reaches the external abductor muscle of the mandible (*e. b. md.*). Here it divides into two parts—(1) an outer

portion, the **Ovarian** (*ov. a.*) [or **Spermatic**] **artery**, which follows the course of the gonads, and (2) an anterior portion, the **Antennary artery** (*a. art.*), which passes around the front of the fore-gut and supplies the organs in the region of the head.

The main portion of the lateral artery, after leaving the heart, dips down gradually until it reaches the external abductor muscle of the mandible (*e. a. md.*). The antennary artery still continues to pursue a deeper course, but the ovarian [or spermatic] artery becomes more superficial. When the gonads are well developed the main artery and the gonadal branch are partly embedded in the substance of the gonad, but when the reproductive organs are small these parts of the artery are quite superficial.

#### **Branches of Main Lateral artery—**

*Branch to the Hind-gut.* This arises on the inner side of the artery just behind the internal adductor muscle of the mandible. It passes downward and inward to that portion of the hind-gut beneath the front part of the heart.

*Branch to the Digestive Gland.* This is a large branch arising immediately in front of the branch to the hind-gut. It passes outward and gives off numerous branches to the digestive gland and also to the hypodermis in this region.

*Branch to the Cardiac Fore-gut.* In front of the internal adductor muscle of the mandible a large branch is given off on the inner side. It passes through the substance of the gonad and breaks up into a complicated network on the lateral and dorsal walls of the cardiac fore-gut. This branch supplies the muscles of the fore-gut.

*Branches to the Hypodermis.* Throughout the whole

course of the lateral artery and its branches small arteries are given off which supply the hypodermis.

*The Ovarian [or Spermatie] Branch (ov. a.).* This follows the course of the gonads, and sweeps round near to the outer edge of the carapace. Numerous branches are given off to the gonads and also to the hypodermis.

*The Antennary Branch (a. art.).* This passes anteriorly and dips downward as it sweeps around the fore-gut. It passes over the paragastric lobe of the bladder and divides into an outer and an inner portion. The *outer* branch dips downward and outward and gives branches to the external adductor muscle of the mandible. It then passes outward to the hypodermis and supplies also the hepatic lobe of the bladder. The *inner* branch passes inward and supplies the antennae and the front part of the head. It also sends branches to the anterior gastric muscles and to the main vesicle and the paragastric and oesophageal lobes of the bladder.

**Hepatic artery** (Pl. VIII, fig. 51, *h. art.*). Owing to the fact that this artery dips down immediately on leaving the heart, and becomes deeply embedded in the digestive gland, it is rather difficult to locate. Hence several workers at the Brachyura have neither figured nor described this artery, and some have described other arteries as the hepatic artery. Milne-Edwards,\* in his description of *Maia*, has designated as the hepatic artery those branches of the sternal artery which supply the digestive gland. Brooks† has called the lateral (ophthalmic) artery by the name of hepatic artery.

The hepatic artery of each side arises from the ventral side of the anterior region of the heart, its origin being beneath and slightly external to that of the lateral

\* Milne-Edwards. *Hist. Nat. des Crustacés.*

† Brooks. *Handbook of Invertebrate Zoology.*

artery. Immediately on leaving the heart it dips downward and makes an outward sweep in the deeper parts of the digestive gland. Near its origin on its inner side it gives off a branch which goes to the hind-gut. There are also other small branches which supply various parts of the gland. The main artery, however, divides into two branches, the posterior of which sweeps outward embedded in the posterior part of the digestive gland. The anterior branch passes beneath the gonad and the external adductor muscle of the mandible and supplies the anterior portion of the gland.

**Posterior aorta** (Superior abdominal artery) (Pl. VIII, fig. 51, Pl. IX, fig. 53, *sa. art.*). This arises as a median vessel from the posterior end of the heart. Just after leaving the heart it gives off at each side a small vessel. This passes forward and downward beneath the pericardium, and supplies those parts of the reproductive organs lying beneath the pericardium, and also some of the muscles of the Basi-Ischium of the Chela.

Immediately above the hind-gut caecum a second pair of branches arises. These are the **Postero-lateral arteries** (*pl. art.*), and have several complicated branches. The main branch passes outwards above the coils of the caecum and divides into two vessels. The anterior vessel passes forward and gives off branches to the extensor muscles of the coxopodites of the four walking legs. The posterior branch supplies the muscles extending from the "flanks" to the carapace, and also gives a rich blood supply to the coils of the hind-gut caecum.

Behind the origin of the postero-lateral arteries the posterior aorta enters the abdomen. As the arrangement in the two sexes is somewhat different, these will be described separately.

**Female.** The aorta passes down the abdomen



above the hind-gut, but not in the median line. As it passes backward it gradually crosses over to the right side. In each of the second, third, fourth and fifth abdominal segments a pair of arteries is given off to the appendages. At the posterior end of the fifth segment the aorta divides into two branches. The right branch follows the course of the aorta. The left branch crosses over the hind-gut and is continued down the left side of the hind-gut parallel to the right branch. Both branches pass into the telson, where they break up into fine branches. Throughout the abdomen small branches are given off from the posterior aorta to the hind-gut, to the abdominal muscles and the muscles of the abdominal appendages.

**Male.** There are only two pairs of arteries given off from the posterior aorta. These are in the first and second abdominal segments and supply the two pairs of appendages. As the aorta passes backward it crosses over to the *left* side, and in the fifth segment it bifurcates, the right branch crossing over the hind-gut. As in the female, there are also innumerable small arteries given off to the hind-gut and to the abdominal muscles.

**Descending artery\*** (Pl. IX, fig. 56, *d. art.*). This leaves the heart at the posterior end close to the origin of the posterior aorta. It is an extremely wide vessel which passes almost directly downward on the right side of the hind-gut until it nearly reaches the anterior part of the "sella turcica," where it turns suddenly forward. It continues to pass downward and forward, and between the muscles of the fourth and fifth thoracic appendages it passes through the foramen

\* The term *sternal artery* is generally given to this artery, as well as to its continuation along the ventral side of the thorax. I have, however, thought it more fitting to apply the term "sternal artery" only to the ventral portion.

of the coalesced thoracic ganglia. Immediately beneath the nerve chain the artery divides into a short and broad posterior branch and a much longer and narrower anterior branch. Both these branches are continuous and horizontal, and are known together as the *sternal artery*.

**Sternal artery** (Pl. IX, fig. 52, *S.art.*). This is a large and well-defined median artery lying in the thorax below the nerve cord and between the muscles of the thoracic appendages. It is broadest at its posterior portion just behind its connection with the descending artery (*j.d.*). In front of this connection it is continued forward as a much narrower vessel, from which are given off arteries to each of the post-oral cephalo-thoracic appendages, and also to the digestive gland. The arteries supplying these appendages arise separately from the sternal artery, except in the case of the last two pairs of thoracic appendages. The arteries supplying these appendages arise as a single vessel at each side of the posterior part of the sternal artery, each of which divides into two branches, each branch going to an appendage.

The blood supply of the last five pairs of thoracic appendages is very similar, and the artery supplying the chela may be taken as typical of all. This artery (*art.6.*) arises singly from the sternal artery and passes outwards. A short distance from its origin it gives off a large ventral branch which supplies the muscles of the coxopodite and basi-ischium. The main artery passes to the extreme end of the appendage, giving off various small branches to the various muscles of the limb.

Each of the arteries to the maxillipedes (*art. 5*), after giving off its ventral branch, enters the appendage and bifurcates, one branch going to the endopodite and the other to the exopodite.

The arteries supplying the first and second maxilli-

pedes (*art. 3, art. 4*) are not symmetrical. The origin of the artery going to the first maxillipede of the right side is posterior to that of the left. In the case of the second maxillipede the origin of the artery on the right side is anterior to that of the artery on the left.

Just in front of the branches to the first maxillipede the sternal artery bifurcates, each part passing forward and uniting again behind the mouth, thus forming a ring. From this ring arteries are given off to the mandibles and the first and second maxillae (*art. 1, art. 2*).

**Inferior Abdominal artery** (Pl. IX, fig. 52, *ia.art.*). The posterior part of the broad sternal artery is continued as a narrow vessel which runs backwards over the "sella turcica" and down the abdomen beneath the nerve cord and the hind-gut. It gives off a few small branches to the hind-gut and to the flexor muscles of the abdomen.

#### BLOOD SINUSES AND VEINS. (Pl. IX, figs. 54, 55, 56.)

The blood returning from the various parts of the body to the gills is not enclosed in definite vessels, but flows through irregular spaces known as *sinuses*. Generally speaking, all the main organs of the body, such as the alimentary canal, digestive gland, reproductive organs, muscles, &c., have blood sinuses in close contact with them.

Above the cardiac fore-gut there is a large sinus—the **Dorsal sinus**—which is situated above the epigastric lobe of the bladder. There is also a smaller sinus between this lobe of the bladder and the fore-gut. These two sinuses are connected in front.

The dorsal sinus passes down the front of the fore-gut and is connected ventrally with a sinus which passes backward beneath the stomach. At the level of the oesophagus this sinus divides into a right and left portion.

These **Sternal sinuses** pass backward at each side of the ventral part of the thorax between the leg muscles and beneath the pericardium. The two sternal sinuses are not definitely separated from one another, but are connected here and there by irregular sinuses. On the outer side each sternal sinus sends offshoots down the pleural muscle chambers to the base of the gills (fig. 56, *br. S. 4*). These branches or branchial sinuses again unite into a long sinus which runs along the base of the gills. This is the infra-branchial sinus (fig. 55, *i. s.*). The blood sinuses from each of the thoracic legs also pass into the infra-branchial sinus.

From the infra-branchial sinus the blood passes along the afferent branchial sinuses on the outside of each gill.

At the posterior end of the thorax the sternal sinuses are connected with a small abdominal blood sinus.

The sinuses in connection with the digestive gland—the **Hepatic sinus**—and the reproductive organs—the **Ovarian** [or **Spermatic**] **sinus**—open into the sternal sinus at each side. There is a very large sinus below the posterior part of the digestive gland.

The **Branchial sinuses** (*br. s. 1-5*) connect the sternal sinus with the infra-branchial sinus at each side. They are five in number at each side. The first branchial sinus (*br. s. 1*) commences below the anterior end of the pericardium. It passes down the pleural muscle chamber of the second thoracic segment and opens into the infra-branchial sinus near its anterior end. Similarly the second branchial sinus (*br. s. 2*) passes down the third thoracic pleural muscle chamber, the third sinus (*br. s. 3*) is in the fourth pleural chamber, the fourth sinus (*br. s. 4*) is in the fifth pleural chamber, and the last branchial sinus (*br. s. 5*), which commences below the posterior end of the pericardium, passes down the



pleural muscle chamber of the sixth thoracic segment. All the pleural sinuses are below the branchio-cardiac veins, which also run down the pleural muscle chambers.

The **Infra-branchial sinus** (fig. 55, *i. s.*) is a long sinus which runs along each side of the thorax at the base of the thoracic legs and the gills. Posteriorly it extends as far as the last walking leg, and anteriorly almost as far as the metastoma. Into it flow the five branchial sinuses from above, and from its outer and ventral side there enters a narrow sinus from each of the thoracic appendages. From its outer and dorsal side there is given off an afferent branchial sinus to each of the gills.

**Afferent Branchial sinuses** (fig. 55). These sinuses run along the outer side of each gill.

*First afferent branchial sinus* (*af. 1*) goes to the podobranch of the second thoracic somite.

*Second afferent branchial sinus* (*af. 2*) goes to the arthrobranch of the second thoracic somite.

*Third afferent branchial sinus* (*af. 3*) goes to the small podobranch of the third thoracic somite.

*Fourth afferent branchial sinus* (*af. 4*) goes to the anterior arthrobranch of the third thoracic somite.

*Fifth afferent branchial sinus* (*af. 5*) goes to the posterior arthrobranch of the third thoracic somite.

*Sixth afferent branchial sinus* (*af. 6*) goes to the anterior arthrobranch of the fourth thoracic somite.

*Seventh afferent branchial sinus* (*af. 7*) goes to the posterior arthrobranch of the fourth thoracic somite.

*Eighth afferent branchial sinus* (*af. 8*) goes to the pleurobranch of the fifth thoracic somite.

*Ninth afferent branchial sinus* (*af. 9*) goes to the pleurobranch of the sixth thoracic somite.

The **Efferent Branchial veins** (fig. 54) receive the pure blood from the branchial lamellae. They pass down

the inside of each gill. Each efferent branchial vein is a blood vessel having a definite wall.

There are nine efferent branchial veins (*ef.* 1-9) corresponding to the nine afferent branchial sinuses—one for each gill.

The **Branchio-cardiac veins** (*fig.* 54) convey the pure blood from the efferent branchial veins to the pericardium. There are five branchio-cardiac veins at each side. They have definite walls.

*First Branchio-cardiac vein (bc. 1)* receives the first and second efferent branchial veins. It passes up the outer side of the pleural muscle chamber of the second thoracic segment, above the first pleural sinus.

*Second Branchio-cardiac vein (bc. 2)* receives the third, fourth and fifth efferent branchial veins. It passes up the outer side of the third thoracic pleural muscle chamber. The first and second branchio-cardiac veins enter the pericardium together through the *first* opening (see section on Pericardium).

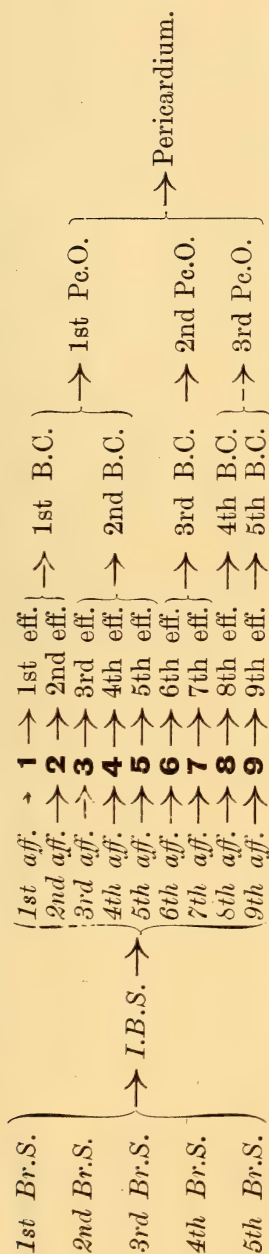
*Third Branchio-cardiac vein (bc. 3)* receives the sixth and seventh efferent branchial veins. It passes up the fourth thoracic pleural muscle chamber. It enters the pericardium by means of the *second* pericardial opening.

*Fourth Branchio-cardiac vein (bc. 4)* receives the eighth efferent branchial vein, and passes up the fifth pleural muscle chamber.

*Fifth Branchio-cardiac vein (bc. 5)* receives the ninth efferent branchial vein and passes up the sixth pleural muscle chamber. The fourth and fifth branchio-cardiac veins enter the pericardium through the *third* pericardial opening.

There are no valves between the branchio-cardiac veins and the pericardium.

## SCHEME OF CIRCULATION OF THE BLOOD TO AND FROM THE GILLS.



## REFERENCES.

- 1 = Podobranch of 2nd thoracic segment.  
 2 = Arthrobranch " "  
 3 = Podobranch of 3rd " "  
 4 = Anterior arthrobranch of 3rd thoracic segment.  
 5 = Posterior " " "  
 6 = Anterior " 4th " "  
 7 = Posterior " " "  
 8 = Pleurobranch of 5th thoracic segment.  
 9 = Pleurobranch of 6th " "
- Br.S. = Branchial sinus.  
 I.B.S. = Infra-branchial sinus.  
 aff. = afferent branchial sinus.  
 eff. = efferent branchial vein.  
 B.C. = Branchio cardiac vein.  
 Pc.O. = Pericardial opening.

### The Blood.

The blood is an almost transparent fluid having a slight pinkish-blue tint (due to the presence of haemocyanin). The colour deepens on exposure to air. The blood consists of an almost colourless lymph in which are found numerous small cells or *amoebocytes*. There are two principal kinds of amoebocytes:—(1) Semi-transparent cells, which are amoeboid and have finely granular protoplasm. There is a well-defined nucleus. (2) Globular cells containing refringent granules. As pointed out by Cuénot,\* these granules are similar to the eosinophilous granules recognised by Ehrlich in the leucocytes of various vertebrates. Hence Cuénot designates the second kind the *Eosinophilous amoebocytes*.† They are composed of an albuminous material.

In the neighbourhood of the cephalic artery, above the fore-gut, is a cellular mass which, according to Cuénot, is a lymphatic gland in which the amoebocytes are formed.

Cuénot has recognised five kinds of amoebocytes in the blood, which are all stages in the transformation of the clear amoebocytes mentioned above. The eosinophilous amoebocytes are also formed from the clear amoebocytes, and mark a stage in the degeneration of the cell. The eosinophilous granules present in the amoebocyte are small and few in number at first. They become comparatively large in size and very numerous until the entire cell is filled with a solid mass. The cell then degenerates rapidly and finally disappears. The granules

\* Cuénot, L. "Études physiologiques sur les Crustacés Décapodes." *Archives de Biologie*, T. XIII, 1895, p. 245.

† The granules readily take the following stains:—Picric acid, eosin, indigo-carmin, fuchsine acid and "orange G." They remain absolutely colourless under the following stains:—Methyl green, dahlia, crystal violet, methylene blue and safranin. (Cuénot).



are probably dissolved in the lymph. The cells themselves are eaten by the young clear amoebocytes, which thus act as *phagocytes*. The phagocytic function is limited to the young cells only. After the appearance of the eosinophilous granules they cease to act as phagocytes.

Cuénot\* claims also to have discovered a phagocytic gland which is quite distinct from the lymphatic gland. It is a swollen mass of cells situated on the terminal branches of the hepatic artery. The cells resemble the free amoebocytes and probably act as phagocytes.

When the blood ceases to flow, coagulation takes place. This is effected by the clear amoebocytes. These cells become changed in their appearance, and they send out numerous fine pseudopodia which unite with those of the neighbouring cells to form a network, in which all the cells are united together. Thus a clot is formed.

### THE "PERICARDIAL POUCH."

At each of the postero-lateral corners of the pericardium there is a structure which Cuénot† designated the "poche pericardiale." In Cancer each pouch lies on the upper part of the posterior thoracic epimera and projects into the branchial chamber. Externally, each pouch is covered with a cuticle which is continuous with the chitinous wall of the branchial chamber. The cavity of the pouch, which is continuous with the pericardial sinus, is to some extent broken up by connective tissue cells and by muscle fibres. The function of these pouches is unknown.

\* Cuénot, L. *Comptes Rendus*, 1903 (No. 137), p. 619.

† Cuénot, L. "Études physiologiques sur les Crustacés Décapodes." *Archives de Biologie*, t. XIII (1895).

## RESPIRATORY SYSTEM.

(Pl. X, figs. 63, 64; Pl. XI, figs. 65, 66, 67).

## RESPIRATORY MECHANISM.

Respiration is effected by means of gills or branchiae, which are outgrowths from the walls of the thorax. The gills do not project directly on to the exterior, but are situated in the branchial chambers at each side of the cephalothorax.

The branchial chambers—one pair. The cavity of each chamber is morphologically a part of the exterior, and its walls are formed by the downgrowth of the carapace at each side. The sub-branchial region of the carapace is closely applied to the coxopodites of the pereopods, and here turns inward to form the wall of the branchial chamber. In transverse section the chamber has a triangular shape (Pl. IX, fig. 56), and its walls may be spoken of as ventral, dorso-lateral and inner. The two former are membranous and are continuations of the inturned edge of the sub-branchial region.

The postero-lateral portion of the digestive gland rests upon the roof of the branchial chamber. Between the floor of the chamber and the sub-branchial region of the carapace there is a mass of connective tissue. In the anterior region of the chamber the floor is raised into a well defined transverse ridge. In a full-sized crab this groove is about  $\frac{1}{4}$  inch in front of the anterior inhalent aperture. In sections through this ridge the epidermis is greatly elongated and has a glandular structure. There are also tegumentary glands below the epidermis. The podobranch of the second thoracic somite is closely applied to the posterior side of this ridge. For the sake of convenience I designate the latter the *branchial ridge*. Its probable function will be discussed below.

The inner wall is well calcified, and is formed by the thoracic epimera ("flanks"). The gills rest on the inner wall.

The development of the branchial chambers would tend to produce a stagnant layer of water around the respiratory organs. But the nature of their function requires that the gills should be in contact with water containing a normal amount of dissolved oxygen. So that, correlated with the formation of the branchial chamber, an arrangement has been effected for producing a constant stream of water over the gills. This necessitates two things—(1) inhalent and exhalent openings in connection with each branchial chamber, and (2) some mechanism for producing the current of water through the chambers.

In the *Macrura* the inhalent opening is situated between the inner edge of the branchiostegite and the base of the thorax. In *Cancer*, however, this opening is considerably smaller. Between the chela and the last pereopod the sub-branchial region is closely applied to the base of the thorax, and the line of separation between the two is guarded by a thick growth of long setae, so that it is highly improbable that any water can gain entrance to the branchial chamber in this region. Above the last walking leg, however, there is a small slit opening into the posterior region of the branchial cavity. This is the **posterior inhalent aperture**. In front of the coxopodite of the chela there is a well-defined transverse opening leading into the anterior part of the branchial cavity. This is the **anterior inhalent aperture**. The latter is guarded in front by the coxa and flabellum of the third maxillipede, which, on their posterior borders, are clothed with long setae. There are also numerous setae on the anterior face of the coxopodite of the chela. These

two sets of setae probably strain the water as it passes through to the branchial chamber.

At its anterior end the branchial chamber is extremely shallow on account of the roof sloping down at a considerable angle. Above the branchial ridge, already referred to, there is an extremely narrow cavity between the top of the ridge and the roof of the chamber. This cavity is continued forward and inward into the pre-branchial chamber.

**P r e - b r a n c h i a l   c h a m b e r s .**    One pair. They are situated at the side of the mouth, each being in front of and connected with the branchial chamber of the same side. Each chamber is produced by the ingrowth of the inner edge of the anterior part of the sub-branchial region of the carapace. Its walls, therefore, are continuous with those of the branchial chamber. The pre-branchial chamber is much smaller and shallower than the branchial chamber. On its anterior and inner side it is connected with the exterior by means of a wide opening—the **exhalent aperture**.

The current through the branchial and pre-branchial chambers is caused by the vigorous action of the scaphognathite. The latter lies in the pre-branchial chamber, and when at rest the anterior surface faces upward. Normally the scaphognathite displays the following movements:—The action of the extensor muscles tends to pull the ventral surface backward. This is followed by a sharp forward blow of the outer lobe of the scaphognathite, caused by the action of the outer flexors. This is immediately followed by an undulating movement of the inner lobe, caused by the accessory muscles and inner flexors. In this way the water is baled out of the exhalent aperture. This current from behind forward is probably assisted by the energetic action of the exopoditic flagella



of the maxillipedes. The extremely active motion of these flagella is quite obvious, and they probably form an accessory current-producing organ of no mean importance.

The normal current, as we have seen, flows from behind forwards, entering at the inhalent apertures and leaving by means of the exhalent aperture. In *Corystes*, *Ateleocyclus* and *Portumnus*, Garstang\* observed that the branchial current was sometimes reversed. Bohn† has extended these observations, and finds this phenomenon is of universal occurrence throughout the Brachyura. In *Cancer* the habit of reversing the branchial current does not appear to be very strongly developed. Bohn suggests that the reversal takes place in order to rest the fatigued muscles of the scaphognathite, as the energetic action is performed by different muscles in the two cases.

The flabella (epipodites) of the maxillipedes pass backward into the branchial chamber. That of the first maxillipede (*f.m.*<sup>1</sup>) is by far the largest, and extends backward throughout the whole length of the branchial chamber lying upon the gills. The flabellum of the second maxillipede (*f.m.*<sup>2</sup>) lies below the gills towards the dorsal side of the epimera. It only extends as far forward as the middle of the epimeron of the fourth thoracic somite. The flabellum of the third maxillipede (*f.m.*<sup>3</sup>) also lies below the gills and on the ventral and outer side of the second flabellum. Its proximal portion forms part of the anterior boundary of the anterior inhalent aperture. It extends backward to the posterior end of the epimeron

\* Garstang. "The Habits and Respiratory Mechanism of *Corystes cassivelaunus*."—*Journal Marine Biological Association*, Vol. IV (N.S.), p. 223.

"The Respiratory Phenomena of *Portumnus nasutus*." *Journal Marine Biological Association*, Vol. IV (N.S.), p. 402.

† Bohn, G. "Sur la Respiration des Décapodes." *Bull. Sci. France et Belg.* T. XXXVI (Ser. 6), 1902, p. 178.

of the fifth thoracic somite. All three flabella are richly clothed with long setae.

In the living animal the flabella have a slow motion over the surface of the gills. Their main function is, undoubtedly, to keep the surface of the gills free from sand and mud which may be suspended in the water carried into the branchial chamber. In a crab from Port Erin the flabellum of the first maxillipede of the right side had been destroyed. In consequence of this the outer surface of the gills of the right side was covered with a layer of fine mud, which must have rendered the outer portions of the gills inoperative. It is doubtful whether the flabella have any function with regard to the formation or regulation of the current of water over the gills. At any rate, this function, if present, has not the importance ascribed to it by Claus.\*

The description of the respiratory mechanism of the *Brachyura* given by Milne-Edwards has become almost classic, and has been accepted by most workers on the subject. According to this explanation, the water enters the branchial chamber at *one* place, viz., in front of the coxopodite of the chela. On entering the branchial chamber the current passes backward below the gills and then forward above the gills and out to the exterior through the pre-branchial passage.

This explanation has been disputed by Bohn,† who states that the water enters the branchial chamber throughout the entire length of the inner edge of the sub-branchial region, the entrance being especially marked at the anterior and posterior inhalent apertures ("l'orifice inspireur antérieur et postérieur," Bohn). According to Bohn, the water entering by the anterior

\* Claus. *Arbeit. Zool. Institut, Wien*, Bd. VI., Hft. 1.

† Bohn. *Op. cit.*

inhalent aperture does not pass backward but passes directly forward to the pre-branchial chamber, and only bathes the anterior part of the sixth gill and all the gills in front of this. The posterior gills are supplied by water entering the posterior inhalent aperture. He denies that there is a backward current caused by the flabella.

My own observations on these points are as follows:—There are two inhalent apertures—the anterior and posterior. Between these two apertures the inner border of the sub-branchial region is closely applied to the side of the thorax, and there appears to be absolutely no inflow of water along this border. Of the two inhalent apertures, the anterior is decidedly the most important. The current of water flowing in through the posterior aperture is very small. I think it extremely probable that some of the water drawn in at the anterior inhalent aperture passes backward, but I do not accept the explanation of Claus—that the backward current is caused by the flabella of the maxillipedes. The presence of the well-defined branchial ridge (see above) in the anterior part of the branchial cavity has suggested another explanation. The ridge is situated on the floor of the branchial chamber immediately in front of the anterior inhalent aperture. It arises near the inner side of the chamber, and passes in front of the aperture as a transverse wall. On the outer side of the aperture it turns backward and outward, and after extending half way down the branchial chamber, it gradually dies away. At its anterior end the branchial chamber is exceedingly shallow, so that the ridge almost extends to the roof of the chamber, leaving only a narrow slit which communicates with the pre-branchial cavity. As the water flows in through the anterior inhalent aperture, it will be drawn forward by the vigorous action of the scaphognathite.

The branchial ridge, however, will act as a formidable barrier, and although some of the water will undoubtedly pass directly over into the pre-branchial chamber, it is reasonable to suppose that some of it will have its course changed by the branchial ridge and will pass backward, following the direction of the latter.

### THE GILLS (Figs. 63, 64).

The gills arise from each side of the thorax and lie upon the inner wall of each branchial chamber, i.e., on the thoracic epimera. According to the terminology introduced by Huxley, the gills may be placed in three categories—the *podobranch* arising from an appendage, the *arthrobranch* arising between an appendage and the epimeron, and the *pleurobranch* arising from the epimeron.

In *Cancer* there are only nine gills at each side. The following is the branchial formula.

Thoracic somites .....	1	2	3	4	5	6	7	8	Total.
Podobranch .....	—	1	1	—	—	—	—	—	2
Anterior arthrobranch .	—	1	1	1	—	—	—	—	3
Posterior arthrobranch.	—	—	1	1	—	—	—	—	2
Pleurobranch .....	—	—	—	—	1	1	—	—	2
Epipodite .....	(1)	(1)	(1)	—	—	—	—	—	(3)
Total .....	(1)	2+(1)	3+(1)	2	1	1	—	—	9+(3)

**First gill.** Podobranch of the second thoracic somite (figs. 63, 64, *g.* 1). It arises from the coxopodite of the second maxillipede between the exopodite and the flabellum. It lies with its outer face in contact with the posterior side of the branchial groove, and its inner face is closely applied to the basal portions of the gills 2 to 6. Its apex points backward and outward. Length 22 mm.\*

**Second gill.** Arthrobranch of the second thoracic somite (*g.* 2). Arises from the arthrodial membrane of

\* The measurements of the gills are taken from a crab having a carapace breadth of 12 cm.



the second maxillipede. It passes directly backward and lies upon the fused epimera of the first and second thoracic somites. Its long axis is at right angles to that of the first gill. Length 25 mm.

**Third gill.** Podobranch of the third thoracic somite (*g. 3*). Arises from the elongated coxopodite of the third maxillipede. It is extremely short and is wedged in between the first and fifth gills, at the base of the latter. Length 7 mm.

**Fourth gill.** Anterior arthrobranch of the third thoracic somite (*g. 4*). Arises, together with the fifth gill, from the arthrodial membrane of this somite. It lies on the thoracic epimera, immediately behind the second gill. Length 26 mm.

**Fifth gill.** Posterior arthrobranch of the third thoracic somite (*g. 5*). Arises from the same place as the fourth gill, and lies immediately behind the latter. Its base is notched in order to receive the third gill. Length 25 mm.

**Sixth gill.** Anterior arthrobranch of the fourth thoracic somite (*g. 6*). Arises together with the seventh gill from the arthrodial membrane between the chela and the fourth thoracic somite. It lies behind the fifth gill. Total length 37 mm.

**Seventh gill.** Posterior arthrobranch of the fourth thoracic somite (*g. 7*). Arises from the same place as the sixth gill and lies immediately behind it. Total length 37 mm.

**Eighth gill.** Pleurobranch of the fifth thoracic somite (*g. 8*). Arises from the epimeron of this somite. Total length 28 mm.

**Ninth gill.** Pleurobranch of the sixth thoracic somite (*g. 9*). Arises from the epimeron of this somite, upon which it lies, immediately behind the eighth gill.

## Structure of a gill (figs. 65, 66, 67).

Each gill is of the phyllo-branchiate type. With the exception of the third gill, they are all pyramidal in shape, their apices pointing upward (with the exception of the first gill, in which the apex points backward). Along the outer side of each gill runs the afferent branchial vessel, and the efferent vessel is situated on the inner side. The gill is composed of numerous lamellae, which have the appearance of the leaves of a book. Each lamella is covered with a thin layer of chitin. This layer is also continued on the outside of the afferent and efferent vessels. The gills, therefore, are covered by part of the general chitinous exoskeleton, and at ecdysis this outer chitinous layer is cast with the remainder of the exoskeleton. In transverse section each gill is triangular (fig. 65). The efferent vessel is situated at the apex of the triangle, and the afferent vessel lies in the middle of the base of the triangle. Stretching across from the afferent to the efferent vessels is the *branchial septum* (*i. b. s.*), which separates the anterior from the posterior lamellae.

In the branchial septum between the afferent and efferent vessels transverse sections reveal the presence of scattered cells, generally having brown contents (fig. 67, *br. e.*). These are excretory cells, and together constitute the branchial excretory organ (see section on Excretory System). Cuénot\* found that when a crab is injected with ammonium carminate or methylene green these substances are taken up by the excretory cells of the branchial septum. These cells, therefore, have the same reaction as the end-sac epithelium.

I have not been able to find any trace of the branchial glands discovered by Allen† in *Palaemonetes*. Cuénot,

\* Cuénot. *Arch. de Biol.*, T. XIII, p. 245.

† Allen. *Q.J.M.S.*, Vol. XXXIV, p. 75.

however, has found them close to the efferent vessels in several of the Brachyura. They do not appear to be present in Cancer.

In longitudinal sections through the gill (fig. 66) the lamellae are seen to be lined by epidermal cells (*ch. ep.*). There is a narrow cavity containing blood separating the upper and lower layer of cells. This cavity, or *lamellar sinus* (*l.s.*) is bridged over in certain parts by the junction of the two layers of epidermal cells. At the free edge of each lamella the lamellar sinus is continuous with the larger *outer lamellar sinus* (*o.l.s.*). This runs around the edge of the lamella, and the epidermal cells in this region are extremely flattened. Each lamellar sinus is in contact with the afferent branchial vessel on the outer side, and the efferent branchial vessel on the inner side. It is in the lamellae that the aeration of the blood is effected.

Dorso-ventral muscles (Pl. VIII, fig. 51,  
Pl. IX, fig. 56, *d. v. m.*).

Extending upward from the membranous roof of the branchial chamber to the carapace, is a series of muscles which may be termed the *dorso-ventral muscles*. The arrangement of these muscles will not be described in detail. There are three sets of muscles at each side (see fig. 51). The outer and middle series are arranged in two parallel lines running antero-posteriorly. The inner set is small, and is situated above the inner region of the branchial chamber. The roof of the chamber is considerably lower at the anterior end than in the posterior region, so that the anterior muscles are consequently longer than the posterior muscles.

Since the roof of the branchial chamber is soft and membranous, it is capable of considerable movement. The

contraction of the dorso-ventral muscles will effect the raising of the branchial roof, and thus produce a corresponding increase in the capacity of the branchial chamber. When the muscles relax, the weight of the superimposed digestive gland and gonad will be sufficient to depress the roof and decrease the volume of the branchial chamber.

Although it is difficult to understand the precise function of these muscles, it must be conceded that their action may be of supreme importance in connection with the branchial chamber, either as a current regulator or as an accessory current-producing organ. It will not be surprising if additional investigations on this point throw new light on some of the problems discussed above.

### EXCRETORY SYSTEM

(Pl. X, figs. 57, 58, 59, Text figs. 11 and 12).

Excretion is performed in three different parts of the body.

- (i) by the Antennary glands and their connections.
- (ii) by the Ferment cells of the digestive gland.
- (iii) by the Branchial excretory organ.

#### (i) THE ANTENNARY GLANDS AND CONNECTIONS.

These form a complicated system of organs at each side of the body. The right and left sides, which are similar to one another are absolutely separate, although in certain places the two parts are in very close contact. This excretory organ is a coelomoduct\*, and may be divided into three portions on each side. The first part, or the **antennary gland** ("green gland," "rein antennarie"), is situated in the cephalic region immediately behind the eye socket. It is a small spongy mass of a

\* Goodrich. Various papers in *Q.J.M.S.*, Vols. XXXVII-XLV.



light green colour, having a triangular shape when viewed from above. At its posterior and inner corner it is connected with the second portion—the **bladder** (“vessie,” Marchal; “nephro-peritoneal sac,” Weldon). This is an extensive thin-walled sac having several large branches. It is easily made out because of the dark brown colour of its walls. Immediately in front of the antennary gland the main portion of the bladder is connected ventrally with the third part—the **ureter**. This is a spacious tube leading downwards and opening to the exterior beneath the *operculum*, which is situated on the ventral side of the basal portion of the second antenna.

(1) The Antennary Gland (Pl. X, figs. 58, 59, Text fig. 11) is made up of two portions. On the dorsal side is a small vesicle—the **end sac** [“saccule,” Marchal] (fig. 58, *end. s.*, Text fig. 11, *e.s.*). From the floor of the end sac are given off numerous blind prolongations, which may either be simple or branched. The epithelium lining the end sac (*e.es.*) is composed of flattened irregularly-shaped cells, some of which project more than others into the cavity of the end sac. Many of these cells contain small yellow oil globules. Marchal speaks of the epithelium of the end sac in *Maia* as being columnar, but in *Cancer* it has a decidedly squamous appearance. Marchal also states that the walls of the end sac are more than one cell thick in places. This does not appear to be the case in *Cancer*. The cells of the end-sac epithelium do not stain so deeply as the epithelial cells of the lower part of the antennary gland.

The ventral portion of the antennary gland is much larger than the dorsal end sac. In sections this lower portion is seen to have a very complicated structure, and is, therefore, known as the **Labyrinth** (fig. 58, Text fig. 11,

*Lab.*). The essential part of the labyrinth is the *Renal tube (tu.)*, the cavity of which is connected in front with the end sac and behind with the bladder. The roof of the renal tube is in close contact with the floor of the end sac. It may be conceived that the lumen of the renal tube was primitively quite simple, so that in such a condition of things the ventral part of the antennary gland would show none of the complicated structure which we designate the labyrinth. The complexity has been produced in two ways. As already mentioned, the floor of the end sac sends downwards numerous branched tubes, the cavity of each tube being connected with that of the end sac, and its walls being lined by the squamous epithelium typical of the end sac. The floor of the end sac is closely applied to the roof of the renal tube, so that these prolongations push before them the epithelium of the renal tube, at the same time breaking up its lumen. Invaginations also appear in the ventral and lateral walls of the renal tube, giving rise to partitions across the lumen of the tube known as *trabeculae*. These ventral and lateral ingrowths are not caused by the extension of the end sac. In sections the dorsal ingrowths of the end sac can always be distinguished from the ventral ingrowths by the fact that the former appear to be lined by two rows of epithelial cells—the squamous epithelium of the end sac, carrying before it the epithelium of the renal tube, the two only being separated by a narrow blood sinus. The ventral ingrowths are only lined by the epithelium of the renal tube, and enclose portions of connective tissue which have been drawn in from tissue surrounding the gland. The epithelium of the renal tube (fig. 59, *e. tu.*) is distinctly columnar, and the protoplasm has a finely striated appearance. The cells are lined by a thin border, which is generally described as a cuticle.

In sections through the antennary gland the following structures may, therefore, be made out:—

*Dorsal.* (a) The main portion of the end sac. This is a simple cavity lined by squamous epithelium, the cells of which do not take the stain well.

*Ventral.* The labyrinth made up of the following parts:—

- (b) Numerous small spaces with an inner lining of squamous epithelium (ventral prolongation of the end sac), and an outer lining of deeply stained columnar epithelium.
- (c) Irregular spaces surrounded by columnar epithelium which is deeply stained. On the side facing the lumen the cells are lined by a fine border. These are portions of the renal tube.
- (d) Small spaces lined by the renal tube epithelium. In the spaces are connective tissue cells and blood. These are the trabecular ingrowths. In some parts the epithelium of the trabeculae fuses with the epithelium of the roof of the renal tube, so that the blood sinus passes right through the labyrinth.
- (e) Between the epithelium of (b) and (c) may be made out small blood sinuses.

(2) The bladder (Fig. 57, Text figs. 11, 12) is extensive and complicated. It is a thin-walled sac readily made out on account of its deep brown colour.

The Main Vesicle is situated above the antennary gland, and its cavity is continuous with that of the renal tube at the inner and posterior end of the antennary gland. In front of the gland it is connected with the ureter. From the main vesicle are given off the following lobes:—

- (a) at the anterior end—Epigastric lobe, Progastric lobe, Antero-lateral lobe, Cerebral lobe.

( $\beta$ ) at the posterior end—Hepatic lobe, Supra-hepatic lobe, Paragastric lobe, Oesophageal lobe.

The **Main Vesicle** ["sac vésical," Marchal] (*M.V.*) is situated below the anterior and outer corner of the stomach and above the antennary gland, with which it is connected at the posterior of the latter. On its ventral side the main vesicle is connected with the ureter immediately in front of the antennary gland.

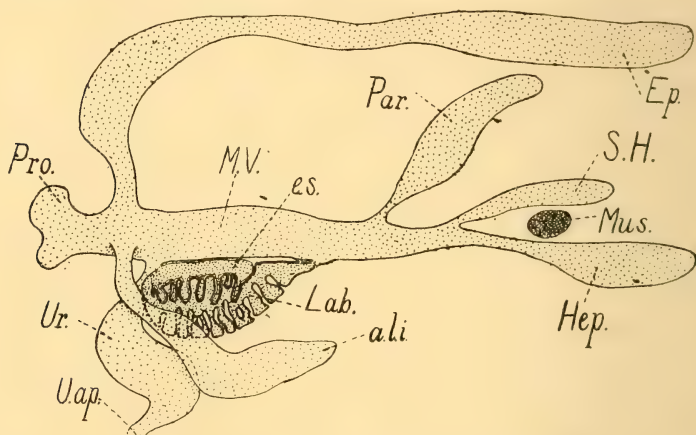


FIG. 11.—Diagrammatic longitudinal section of the excretory system.

- |  |   |
|--|---|
| <i>Ep.</i> = Epigastric lobe.                      | <i>M.V.</i> = Main vesicle.                         |
| <i>Pro.</i> = Progastric "                         | <i>Mus.</i> = External adductor muscle of mandible. |
| <i>Par.</i> = Paragastric "                        | <i>e.s.</i> = End sac.                              |
| <i>S.H.</i> = Supra-hepatic "                      | <i>Lab.</i> = Labyrinth.                            |
| <i>Hep.</i> = Hepatic "                            | <i>Ur.</i> = Ureter.                                |
| <i>a.l.i.</i> = Inner part of antero-lateral lobe. | <i>U.ap.</i> = External aperture of ureter.         |

The **Epigastric lobe** (Fig. 57, *e. lb.*, Text fig. 11, *Ep.*) is the most obvious part of the bladder when dissecting the crab from above. It arises from the anterior end of the Main Vesicle. It passes forwards and upwards along the front wall of the fore-gut and turns back along the dorsal wall, extending as far back as the



pyloric region. It is clearly separated in the middle line from the corresponding lobe of the other side. It is broad anteriorly, and becomes narrower and more irregular in shape towards the posterior end. The outer part of the broad anterior portion is slightly reflected down the side wall of the fore-gut and comes into contact with the paragastric lobe.

The **Progastric lobe** (Fig. 57, *p. lb.*, Text fig. 11, *Pro.*), is, strictly speaking, part of the Epigastric lobe. It is situated close to the connection between the Main Vesicle and the Epigastric lobe. It is on the inner side of the latter, and is closely applied to the front wall of the stomach. The lobes of each side come into very close contact in the median line, and it is only by very careful dissection that they are seen to be separate.

The **Antero-lateral lobe** ["lobe du muscle adducteur," Marchal] (Fig. 57, *a. lb.*, Text fig. 11, *a. l. i.*) arises from the anterior and outer corner of the Main Vesicle. It consists of two parts:—

(a) An inner lobe (Text fig. 12, B, *a. l. i.*), which passes inwards beneath the antennary gland.

(b) An outer lobe (Text fig. 12, B, *a. l. o.*), which passes outwards beneath the digestive gland as far as the origin of the outer adductor muscle of the mandible.

The **Cerebral lobe** (fig. 57, *c. lob.*) arises from the anterior and inner corner of the Main Vesicle. It passes inwards above the cerebral ganglia, and almost meets the corresponding lobe of the other side.

The **Hepatic lobe** ["arriere vessie" (part), Marchal] (fig. 57, *h. lb.*, Text fig. 11, *Hep.*) arises from the posterior and outer corner of the Main Vesicle by a very narrow portion, which passes beneath the outer adductor muscle of the mandible close to its insertion on the mandibular apophysis. The main part of the lobe passes outwards

beneath the digestive gland and follows the course of the gland to its extreme outer and posterior corner. Along the outer edge of the digestive gland the lobe turns upwards and covers the outer part of the dorsal portion of the gland. Owing to its position beneath the digestive gland the hepatic lobe is not readily seen, in spite of its large size. Near the origin of this lobe from the Main Vesicle a small inner lobe is given off, which ends blindly near the posterior oesophageal lobe.

The **Supra-hepatic lobe** (fig. 57, *s.lb.*, Text fig. 11, *S. H.*) is not well developed in Cancer. It arises from the Main Vesicle on the inner side of the origin of the hepatic lobe, and passes above the digestive gland on each side of the fore-gut.

The **Paragastric lobe** (fig. 57, *g.lb.*, Text fig. 11, *Par.*) arises from the posterior end of the Main Vesicle near to the origin of the supra-hepatic lobe. Its outer side is applied to the mandibular apophysis, and on its inner side it comes into contact with the side wall of the fore-gut. It passes up the side of the latter and touches the epigastric lobe.

The **Oesophageal lobe** arises from the inner and posterior corner of the Main Vesicle. It passes inwards and divides into anterior (*as.lb.*) and posterior (*po.lb.*) portions which wrap around the oesophagus, touching the corresponding lobe of the other side in the middle line.

In sections through a young crab (width of carapace 15 mm.) the epithelium of the bladder (Pl. XII, fig. 82) consists of columnar cells  $20\mu$  long and  $15\mu$  wide. The protoplasm is denser near the outer portion of each cell, and the inner portion of the protoplasm is greatly vacuolated. In the outer region of the cell the protoplasm is arranged in longitudinal strands, which gives rise to the

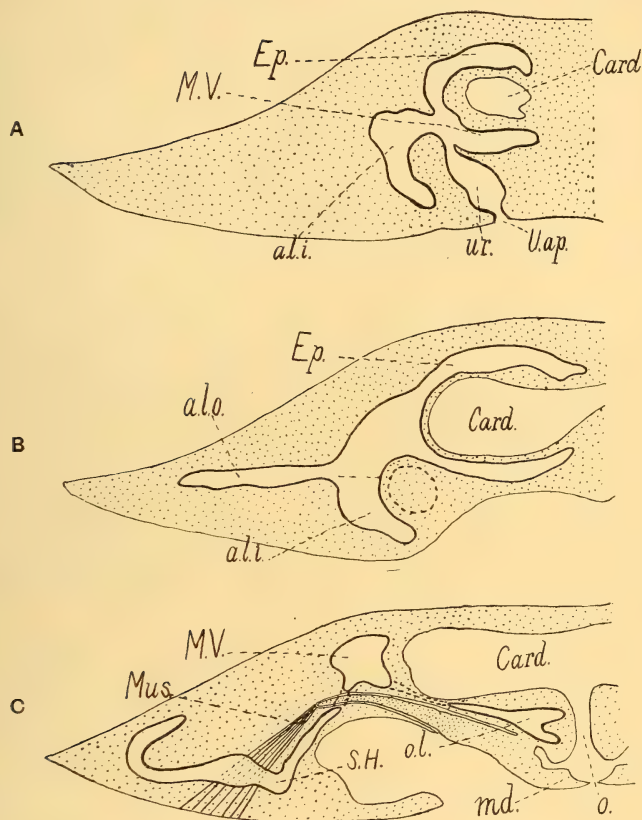


FIG. 12.—Diagrammatic transverse sections through the left half of the body to show the excretory system.

A. = at the level of the external excretory aperture.

B. = at the level of the "green gland." (The gland is shown as a dotted line.)

C. = at the level of the oesophagus. (For S.H. read Hep.)

Card. = cardiac region of the fore-gut. o.l. = oesophageal lobe.

o. = oesophagus.

md. = mandible.

a.l.o. = outer portion of antero-lateral lobe.

(Other references as in Fig. 11).

striated appearance noted by Weldon and Allen. In some cases these striations are carried through to the inner region of the cell, but generally the protoplasm is divided into a deeply-stained outer portion, which exhibits the striations mentioned above, and a more lightly stained inner portion in which the strands of protoplasm are few in number, thus causing the vacuolated appearance. The nucleus of the bladder epithelial cells has a diameter of  $6\mu$ , and is situated near the centre of the cells.

(3) The Ureter (Text fig. 11, 12, A, *Ur.*) is a spacious sac situated on the inner side of the antennary gland, partly in front of and partly below the gland. The connection with the main vesicle is a narrow opening immediately in front of the anterior and inner corner of the gland. The ureter passes downwards, and opens to the exterior on the ventral surface of the proximal portion of the second antenna. It is lined with epithelial cells, which are distinctly larger than those of the bladder and take the stain more distinctly.

The relation of the parts in the neighbourhood of the external orifice is of interest. The proximal region of the ventral side of the second antenna is occupied by a small, irregularly-shaped plate—the *operculum* (Pl. II, fig. 5, *op.*), which is freely movable. The movement is possible because of its connection, by means of a flexible membrane, with the surrounding hard parts. The membrane forms a pocket-like invagination around the operculum, and is deepest on the inner and posterior side, so that the movement is greatest on this side when the operculum is raised. When the operculum is elevated it is seen that the membrane is perforated by a distinct orifice on the inner and posterior side. This is the *excretory orifice*. Hence Marchal\* termed the membrane

\* Marchal. "Appareil excréteur des Crustacés Décapodes." *Arch. Zool. exp. et gén.*, T. X (Ser. 2), 1892.



surrounding the orifice the *excretory membrane*. He states that the excretory fluid is not ejected as the result of muscular contraction around the walls of the sac-like ureter. There are no muscles in the walls of the ureter. The outflow is of a passive character, and takes place whenever the excretory orifice is opened. Although it is probable that the operculum does not fit tightly enough to prevent the outflow of the excretory fluid, yet it is when the operculum is closed that the fluid ceases to escape. When the operculum is drawn down closely into its socket, the lips of the excretory orifice are pressed together because of the contraction of the excretory membrane. On the contrary, when the operculum is raised the membrane is extended and the orifice opens. As shown by Marchal, the movements of the operculum are under the control of two muscles—an *elevator muscle* for extending the operculum membrane, and a *depressor muscle* for drawing the operculum down into its socket.

#### Mode of Excretion.

According to Marchal, the excretory fluid is not produced by diffusion across the epithelial cells of the antennary gland and bladder, but is the result of an actual breaking away of a part of each of the epithelial cells. An examination of the excretory fluid will show that there are numerous bladder-like vesicles and also cells floating in the fluid. In sections of the bladder, and also in teased preparations, one can see, as stated above, that the protoplasm is highly vacuolated on the inner side of each epithelial cell. Moreover, in some cells there is one large vacuole, or vesicle, projecting into the lumen of the bladder and surrounded by an extremely thin layer of protoplasm. In the interior of the vesicle is a fluid sometimes containing refringent

granules. Each vesicle which contains excretory fluid and excretory granules ultimately breaks free from the cell and floats away in the excretory fluid.

In addition to this method, it is highly probable that some of the excretory fluid passes through the epithelial cells into the cavity of the bladder by the ordinary process of diffusion.

The above mode of excretion is not only performed by the cells of the bladder, but also, according to Marchal, by the cells of the labyrinth, in a slightly modified manner.

As stated above, the cells of the renal tube in the labyrinth appear to be lined by a thin cuticle. Marchal states that it is *not* a cuticle, but that the appearance is due to a row of very small vacuoles lining the inner side of each epithelial cell. These vacuoles gradually increase in size, fuse together, and the single large vesicle formed is liberated into the lumen of the renal tube, in a very similar manner to the method described above in the case of the bladder.

In the cavity of the end sac the fluid contains small vesicles containing yellow oil globules. These have been excreted from the epithelial cells of the end sac, which, as mentioned above, often contain yellow oil globules.

In addition to these, Marchal states that in *Maia* *entire* epithelial cells break free from the walls of the end sac.

At first Marchal believed that in *Maia* the wall of the end sac was composed of a single layer of cells, and he expressed surprise that it was possible for cells to break away bodily from such a layer without breaking the continuity of the walls of the end sac. Finally he decided that the wall was several cells thick in certain places, and that it was from these places that the cells found in the

lumen of the end sac had broken free. Whatever may be the condition of things in Maia, there is no doubt that in Cancer the walls of the end sac are uniformly only of one cell in thickness. As in Maia, there are cells in the cavity of the end sac, and I agree with Marchal that these are epithelial cells of the end sac which have broken away. There appears to be nothing surprising that certain cells of this single layer of epithelial cells should be gradually nipped off by the activity of the surrounding cells and thus shed into the lumen of the end sac. An examination of serial sections through the end sac reveals cells in every stage of this process of shedding. This explains why certain cells of the end sac epithelium project farther into the lumen than others, as described above.

Cuénot investigated the excretory organs of Crustacea by injecting various colouring matters into the body of the living animal. He has placed these colouring matters into three groups, according to where they were eliminated.

- (1) Fuchsin acid, Bismarck brown, safranin, indigo-carmin, etc.
- (2) Methylene green, ammonium carminate, etc.
- (3) Methylene blue.

After such injections it was found that the cells of the renal tube of the labyrinth and the cells of the bladder have a decidedly alkaline reaction and excrete the substances of the first category. The cells of the end sac, on the other hand, have an acid reaction and eliminate the substances of the second category.

By the above method of injection Cuénot discovered that in addition to the antennary gland and its connections there are two other kinds of excretory cells, viz.:—The ferment cells of the digestive gland, and the cells in the branchial septum.

## Development of the Antennary Gland.

According to Waite,\* who studied the development of the gland in *Homarus*, the end sac alone arises from the mesoderm when the embryo is only five days old, and its lumen is for a long time completely enclosed by mesodermal cells. An ectodermal ingrowth (which ultimately becomes the renal tube of the labyrinth) occurs at about the twenty-eighth day. The lumen of the end sac does not become continuous with that of the labyrinth until the embryo is nearly 300 days old. The complications in the walls of the renal tube to form the labyrinth do not occur until the third larval stage. The bladder is formed by a dorsal outgrowth of the ectodermal tube. Therefore, only the cavity of the end sac represents part of the original coelom. The renal tube of the labyrinth, the bladder and the ureter are all ectodermal in origin. Although the development of the green gland in the *Brachyura* has not been investigated, there is no reason to believe that it presents any striking differences from that of the *Macrura*.

## (ii) FERMENT CELLS OF THE DIGESTIVE GLAND.

Part of the contents of the ferment cells are of an excretory nature, and when the contents of these cells pass down the digestive tubules into the mid-gut the excretory products are separated away and are carried to the exterior along with the faeces. The ferment cells of the digestive gland take up methylene blue when this colouring matter is injected into the body of the living animal. The large coloured mass inside each ferment cell is coloured light blue. Inside this mass there are small bodies, which take a dark blue stain. According to Cuénot, in five days after the experiment the blue

\* Waite. *Bull. Mus. Harv.*, Vol. XXXV, No. 7 (1899).



stain will pass out into the lumen of the tubule and thence to the alimentary canal, where it is got rid of along with the excrement.

### (iii) BRANCHIAL EXCRETORY ORGAN.

This is found in the gills in that portion of the tissue situated between the afferent and efferent branchial veins. According to Cuénot, the excretory cells are continued along the sides of the branchio-cardiac veins. When the crab is subject to Cuénot's system of injection, it is found that the cells of the branchial excretory organ act like the cells of the end sac. They have an acid reaction and eliminate substances of the second category.

### NERVOUS SYSTEM.

The nervous system of the *Brachyura* (*Carcinus maenas*) has been investigated in detail by Bethe.\* It is proposed to give here only a short account of the nervous system of Cancer.

The nervous system may be described briefly as consisting of two main nerve masses—the fused pre-oral cerebral ganglia and the fused ganglia of the post-oral region. The two are connected by a pair of commissures which pass round the oesophagus. With the cerebral ganglia are connected the nerves supplying the eye, antennules and antennae. All the post-oral appendages and somites are innervated from the posterior nerve mass which lies in the thorax. At each side of the oesophagus there is a ganglion on the commissure, from which arises the stomatogastric nerves supplying the fore-gut.

The brain is the centre of co-ordinated movement, and each ganglion of the ventral nerve mass is the reflex centre for the appendage which it supplies.

\* Bethe. *Arch. f. Mikr. Anat.*, Bd. XLIV (1895), pp. 579-622; Bd. L (1897), pp. 460-546, 589-639; Bd. LI (1898), pp. 382-452.

### The Brain.

The Brain (cerebral ganglia, *c.g.*) is situated above the anterior end of the epistoma. It is roughly rectangular when viewed from above, and is formed of a complex mass of nerve cells and fibres. The anterior half of the brain is connected with the nerve fibres supplying the eye and optic peduncle. From the posterior half arise the nerves innervating the antennules, antennae, the sense organs of the antennules, and also the nerves supplying the integument. The nerve fibres from the different parts become aggregated in the brain in definite masses or *neuropiles* ("Punksubstanz," Leydig). Between the neuropiles there are numerous nerve cells more or less closely packed. The main neuropiles are as follows:—

Connected with the optic fibres. The *antero-superior*, *median* and *posterior optic neuropiles*, all situated in the anterior half of the brain. Also the *inferior optic neuropile* extending below the others.

Connected with the oculomotor fibres. The paired *lateral oculomotor neuropiles* situated on the outer side of the optic neuropiles, and also a *median oculomotor neuropile* lying in the middle line behind the optic neuropiles.

Connected with the first antenna (antennule). The *median neuropile of the first antenna* situated in the middle line below the median oculomotor neuropile. The *lateral neuropiles of the first antenna* situated ventrally at each side, behind the inferior optic neuropiles.

Connected with the second antenna. There are three neuropiles situated at each side of the posterior region of the brain, viz., the *median*, *posterior* and *lateral neuropiles of the second antenna*.

Connected with the tegumentary nerves. The

*superior and inferior tegumentary neuropiles* situated in the posterior region of the brain, slightly anterior to the neuropiles of the second antenna.

At each side of the brain there is a globular mass of radiating fibres lying between the oculomotor and the tegumentary nerves. This is the *globulus*. There is a tract of nerve fibres extending from the globulus to the median optic neuropile. It is probable that some of the fibres of the otocyst nerve arise from the globulus.

The chief groups of nerve cells in the brain are as follows:—

The *supero-median* cells are on the inner side of the antero-dorsal region of the brain.

The *infero-median* cells are situated on the ventral side of the posterior part of the brain near the median line.

The *supero-lateral* cells are situated dorsally on the inner and anterior side of the globulus.

The *infero-lateral* cells extend along the inner side of the globulus on the ventral side of the brain.

The *anterior globular* cells are situated ventrally on the inner and anterior side of the globulus.

The *posterior globular* cells lie above and behind the globulus at its outer and posterior side.

The following nerves are connected with the brain (fig. 68):—

**Optic nerve** (*o. n.*). One pair. Each arises from the dorsal side of the brain at its anterior corner. The fibres are continuous with those of the various optic neuropiles. It runs outward and forward at an angle of  $45^{\circ}$  with the longitudinal axis, and passes into the distal part of the optic peduncle, where the latter articulates with the proximal part of the peduncle. In the swollen part of the peduncle the nerve becomes enlarged to form the optic

ganglion (fig. 69, *o.g.*). From this ganglion nerve fibres are given off, which pass through the basement membrane and innervate the various ommatidia of the eye (see figs. 69, 70).

**Oculomotor nerve** (*om. n.*). One pair. These arise from the brain immediately behind the optic nerve. Each passes outward behind the optic nerve, and supplies the optic peduncle and the muscles connected with it.

**Antennulary nerve** (*a.<sup>1</sup> n.*). One pair. At each side this nerve appears to be single, but it is composed of two different kinds of fibres, having different functions and arising from different centres in the brain. For this reason the two nerves should be described separately, as in the case of the optic and oculomotor nerves. The main branch innervates the antennule, and is connected in the brain with the fibrils of the median neuropiles. The fibres innervating the olfactory and tactile setae are probably connected with the lateral neuropiles. The otocyst branch is connected with the lateral neuropiles, and also with the globulus. It passes out from the brain together with the fibres of the main branch, but the two kinds soon separate and those innervating the otocyst pass outwards, and the fibres are connected with ganglion cells at the base of the otocyst setae. The antennulary nerve arises from the middle of the ventral surface of the brain, but in *Cancer* it apparently leaves the brain near the anterior end.

**Tegumentary nerve** (*t. n.*). One pair of broad nerves, which leave the brain near the postero-lateral corner. Each passes outwards almost at right angles to the longitudinal axis, and divides into two main branches. The anterior branch supplies the integument in region of the rostrum. The outward branch sweeps backwards and outwards, giving off small branches to the integument.



**Antennary nerve** (*a.<sup>2</sup> n.*). One pair of small nerves, which arise from the ventral side of the brain immediately behind the tegumentary nerves. They are connected with the fibres of the neuropiles of the second antenna. Immediately on leaving the brain each passes beneath the tegumentary nerve and enters the muscle chamber of the second antenna.

The **commissures** (*Com.*). One pair of rather large nerves, which arise from the posterior side of the brain. They pass posteriorly on each side of the oesophagus, and are connected with the ventral nerve mass in the thorax. At each side of the oesophagus there is a *paroesophageal ganglion* (*p. g.*), and behind the oesophagus the two commissures communicate by means of a transverse *post-oesophageal connective* (*n. po.*). From the paroesophageal ganglia arise the stomatogastric nerves, and immediately behind the ganglion there is a small nerve (*n. m.*) supplying the muscles of the mandibles.

#### Ventral Nerve Mass.

The ventral nerve mass (*t. g.*) is situated above the sternal artery in the third and fourth thoracic somites. It is partly supported by the median plate of the endophragmal system. It contains nerve elements representing the post-oral cephalothoracic ganglia and the abdominal ganglia. It is not possible to make out all these ganglia from dissections, but they may be distinguished in stained preparations and in sections. Slightly behind the centre of this fused ganglionic mass is a foramen (*n. f.*), through which passes the descending artery.

At its anterior end, where it is connected with the commissure, the ventral nerve mass is narrower than in its posterior portion. In this anterior portion it is

possible to make out, in suitable preparations, evidences of six pairs of ganglia belonging to the last three cephalic and the first three thoracic somites. Behind this region five pairs of larger ganglia may be distinguished more readily. From these arise the nerves supplying the five pairs of pereopods and the last five thoracic somites. Between the last two ganglia is a median swelling, which is composed of the six ganglia belonging to the abdominal somites.

The following nerves arise from the ventral nerve mass:—

**First nerve** (*n. 1*). One pair. Each arises close to the connections between the commissure and the ventral nerve mass. It contains fibres from the first three ganglia of the nerve mass. It passes forwards parallel to the commissure and divides into three branches, passing to the mandible, first maxilla and second maxilla respectively.

**Second nerve** (*n. 2*). One pair. Each arises behind the first nerve, and its fibres are connected with the cells of the fourth ganglion of the nerve mass. It passes forward and slightly outward, and supplies the various parts of the first maxillipede.

**Nerves 3-9** (*n. 3-n. 9*). These are all paired, and are connected with the fifth and following ganglia of the ventral mass. Each nerve supplies the appendage of its own somite, and its course is very similar to that of the second nerve. Nerves 5-9, however, are larger than the others, and the posterior nerves pass outwards and backwards.

**Abdominal nerve** (*n. ab.*). This is a median nerve, which passes backward in the median line. It arises from the fused abdominal ganglia at the posterior end of the ventral nerve mass, and contains nerve fibres from all the

abdominal ganglia. It passes backward along the median line of the "sella turcica" and along the ventral region of the abdomen. Small nerves are given off to each somite of the abdomen.

According to Jolyet and Viallanes,\* the centres of the moderator and accelerator nerves of the heart are in the anterior part of the ventral nerve mass. The cardiac nerve of the *Macrura* does not appear to be present in the crabs.

### The Stomatogastric System.

This consists mainly of nerves arising from the paroesophageal ganglia. These nerves fuse to form the stomatogastric nerve, which supplies the anterior and dorsal regions of the fore-gut. There is also the posterolateral nerve arising behind each paroesophageal ganglion.

There are two main nerves arising from each paroesophageal ganglion. These pass below the commissure, and, passing forward, they fuse with each other and with the similar nerves of the other side to form the main stomatogastric nerve. The *ventral* nerve (*st. i.*) arises from the outer side of the ganglion, and immediately passes below the lateral dilator muscle of the oesophagus, to which it gives small branches. It passes below the commissure and innervates the anterior dilator muscles of the oesophagus. It then turns upward and fuses with the similar nerve of the other side and with the *dorsal* nerve. The latter nerve (*st. s.*) arises from the anterior and outer side of the paroesophageal ganglion. It passes immediately below the commissure, and gives off a small nerve to the anterior walls of the oesophagus. In the median line it fuses with the corresponding nerve of the opposite side, and also with the ventral nerve.

The **stomatogastric nerve** (*st. n.*) is formed by the

\* Jolyet et Viallanes. *Comptes Rendus*, CXIV (1892), p. 189.

fusion of the two ventral and dorsal roots, as described above. It passes up the anterior wall of the cardiac fore-gut as a median nerve. About half way along this wall the nerve enlarges to form the *stomatogastric ganglion* (*st. g.*). From this point the nerve proceeds backward along the dorsal side of the fore-gut, and almost immediately gives off two large branches—the **lateral gastric nerves** (*l. g. n.*). Each lateral gastric nerve passes over the anterior cardiac muscle, which it innervates, and gives rise to a nerve plexus in the dorsal walls of the cardiac fore-gut. Both nerves also give rise to an internal branch, which passes inwards and joins again with the stomatogastric to form a large ganglion. Behind this ganglion the stomatogastric nerve bifurcates. Each branch, which is known as the **posterior gastric nerve** (*p. g. n.*), passes backward to the pyloric fore-gut. Here the two nerves join again, thus forming a ring. From the posterior end of this ring three nerves are given off—one to the hind-gut (*n. i.*), one to the digestive gland (*n. l.*) and one to the integument (*n. t.*). The muscles in this region of the fore-gut are also innervated from the posterior gastric nerves.

The **postero-lateral nerve** (*p. n.*) of each side arises from the inner side of the commissure, immediately behind the paroesophageal ganglion. It passes backward, and innervates the posterior dilator muscle of the oesophagus. It then passes upward along the posterior wall of the fore-gut, and supplies the muscles in this region.

#### SENSE ORGANS.

##### The Eye.

Each eye is situated at the distal extremity of the long optic peduncle. The peduncle is clearly divided into two portions:—(1) A long narrow proximal part, which



meets the peduncle of the other side in the median line above the first cephalic sternum. This proximal portion is not seen from the exterior. (2) A shorter and broader distal portion, which is the part seen from the exterior. The two parts are separated by a region of soft chitin, which allows of considerable movement between the two parts. At the distal extremity of the peduncle is a small black area—the *cornea*—which defines the external surface of the eye. The cornea would be almost circular were it not for the presence of two small tubercles which invade the dorsal border of the black area, and thus give it a somewhat irregular shape. The cornea is composed of a thin layer of chitin, which is continuous with the thick, strongly calcified integument covering the remainder of the distal part of the peduncle.

The thick calcified integument has the usual layer of epidermis beneath, resting upon a basement membrane. In the region of the eye, the cellular layer on the inner side of the cornea is extremely thick, and is known as the *ommateum*. On the inner side of the ommateum is a well-defined basement membrane, which is continuous with that of the ordinary epidermis. The ommateum, therefore, may be regarded as a differentiation of the epidermis, with which it is continuous.

An examination of the surface of the cornea reveals the presence of numerous small hexagonal facets. Vertical sections through the eye show that this sub-division of the cornea is not merely superficial, but is continued through to the inner side of the chitinous layer. The cornea may, therefore, be said to be composed of numerous hexagonal prisms, which are packed closely together. On the inner side of the cornea the ommateum is divided into numerous elements, which correspond in number and position to the corneal facets. Each element of the ommateum is known

as an ommatidium and fits below a corneal facet, and extends from the cornea to the basement membrane. All the ommatidia have the same essential structure.

*Structure of an ommatidium.*

Each ommatidium may be conveniently divided into proximal and distal regions. The outer parts of both these regions are defined by the presence of pigment (fig. 69, *pg. i.*, *pg. o.*).

Underlying the cornea is the flattened corneagen. Below this are the vitrellar cells, the distal region of which enclose the crystalline cone. The vitrellae are surrounded by pigment cells, which are densest on a level with the proximal region of the crystalline cone. At the proximal end of the vitrellae are the pigmented retinulae which surround the rhabdome. The retinulae are in contact with the nerve fibres from the optic ganglion, and the proximal end of the rhabdome is in contact with the basement membrane.

The **corneagen** ["corneal hypodermis," Parker] (fig. 70, *corn.*) lies immediately below the cornea, which is a product of the corneagen cells. It consists of two flattened tile-like cells.

The **vitrellae** ["cone cells," Parker] (*vit.*) lie immediately below the corneagen. Transverse sections show that there are four vitrellae in each ommatidium. Their distal extremities are applied to the base of the corneagen. Passing inward the cells become narrower. Distally they enclose the crystalline cone, which is secreted by these cells. Surrounding the vitrellae are two **pigment cells** (*pg. c.*), which are continued inward as fine processes and eventually come into contact with the retinulae. (Fig. 72 is a section through the vitrellae of a single ommatidium, and shows that there are four vitrellar

cells surrounded by two pigment cells.) Between the vitellae and the pigment cells there are intercellular spaces, which are larger at the proximal end of the vitellae.

The **retinulae** (*ret.*) are seven pigment cells which surround the rhabdome, and extend from the proximal portions of the vitellae to the basement membrane. Distally each retinula ends in a rounded knob, which contains a nucleus (fig. 71 shows the disposition of the retinulae around the rhabdome). At their distal ends the retinulae are extremely large, and surround the rhabdome in this region so as to completely hide it. The concentration of the pigment in this region gives rise to a well-marked pigment band (fig. 69, *pg. i.*). Proximally the retinulae are not so large, and the rhabdome can be seen quite distinctly between them. The rhabdome has a peculiarly striated appearance, which is caused by the arrangement of the pigment granules of the retinulae. The optic nerve fibres pass into the retinular cells, so that it is this part of the eye which is sensitive to light.

The **rhabdome** (*rhab.*) is a rod-like structure in the centre of the retinulae. According to Watase,\* the rhabdome is a chitinous structure produced as a secretion from the retinulae. Parker† states that transverse sections show that the rhabdome is composed of four parallel rods, and he further affirms that these four rods are the inner extremities of the four vitellae (cone cells).

The *optic nerve fibres* perforate the basement membrane and end in the retinulae.

Each ommatidium, therefore, may be said to consist

\* Watase, S. "On the Morphology of the Compound Eyes of Arthropods," *Q. J. M. S.*, Vol. XXXI, p. 143.

† Parker, G. H. "The Histology and Development of the Eye in the Lobster," *Bull. Mus. Comp. Zool. Harv.*, Vol. XX, No. 1.

— "The Compound Eyes in Crustaceans," *loc. cit.*, Vol. XXI, No. 2,

of a series of cells which on their outer side receive and concentrate the rays of light. These are transmitted to the retinulae by means of the transparent vitrellae. The retinulae are connected with the nerve fibres, and are, therefore, the important part of the eye. Each ommatidium is surrounded by a layer of pigment, so that the sensitive retinulae are situated at the bottom of a tube, which is completely separated from the tubes of the other ommatidia because of the presence of the pigment. Therefore, the retinulae of an ommatidium can only receive light through the small corneal facet at the distal extremity of the particular ommatidium.

The **cornea** (*cn.*) is composed of three layers. On the outside is a thin structureless layer—the *cuticle* (*cut.*). Beneath this is an outer *pigmented layer* (*pig. l.*), to which the colour of the cornea is due. Below the pigment layer is the *deeper layer*. Both inner layers exhibit longitudinal striations.

According to Watase, the corneagen, vitrellae and retinulae are all modified epidermal cells, which, in the case of the vitrellae and retinulae, have grown inward. The cornea is a chitinous secretion of the corneagen. The crystalline cone is primarily a chitinous secretion of the vitrellae, and the rhabdome is a chitinous rod secreted by the cells of the retinulae.

### The otocyst.

The otocyst is found in the basal segment of the antennule. It is a sac lined with a layer of chitin, which is continuous with the outer chitinous integument. In the megalopa stage and in the young crabs the otocyst is open to the exterior, and in these stages otoliths are present in the sac. In large crabs, however, there are no otoliths, and the sac is completely closed except



immediately after ecdysis, when the otocyst is connected with the exterior by means of a transverse slit on the dorsal side of the basal segment of the antennule. This slit is quite obvious in the hard crab. The walls of the sac project into the lumen at three places—(1) in the postero-lateral wall (2) in the posterior wall, and (3) the anterior part of the floor.

There are three kinds of setae situated on the walls of the otocyst and projecting into the lumen.

The **hooked setae** ["Hakenhaare," Hensen] (Pl. XI, fig. 75) are found on the convex portion of the posterior wall of the otocyst. These setae are characterised by having the distal extremity inclined at a considerable angle to the proximal portion, sometimes as much as  $90^{\circ}$ . The distal portion of the shaft has fine barbs arising from it. The base of the shaft is sunk into a socket-like depression. The total length of the hook hairs is about  $55\mu$ .

The **thread setae** ["Fadenhaare," Hensen] are found on the anterior part of the floor. They are the largest setae present in the otocyst, and are about six times as long as the hook hairs. There are well-defined barbs arising from the shaft. The base of each seta lies in a cup-shaped depression of the chitinous wall.

The **grouped setae** ["Gruppenhaare," Hensen] (fig. 76) are situated on the lateral walls of the otocyst, below the closed entrance of the sac. They are about  $140\mu$  in length, and have blunt shafts. There are no barbs present.

The three kinds of setae are innervated from the otocyst nerve, and according to Prentiss\* there is one nerve element for each seta. The same author states that

\* Prentiss, C. W. "The Otocyst of Decapod Crustacea: its structure, development, and functions," *Bull. Mus. Comp. Zool. Harv.*, Vol. XXXVI, No. 7.

the otocyst does not become functional until the megalopa stage.

Hensen and the early observers believed that the otocyst was an auditory organ. Hensen found that the "auditory" setae were individually sensitive to sound vibrations of different frequency, and concluded that in the lobster the auditory organ had a range of three octaves.

Kreidl was the first to deny that the otocysts possessed an auditory function. He substituted iron filings for the otoliths, and the experiments led him to believe that this organ served the function of equilibration.

Bethe, while accepting Kreidl's results, did not reject the idea that the otocyst was also an auditory organ.

The researches of Prentiss led him to believe that the otocyst was a static organ solely. It is probable that in the *Brachyura* the hooked setae and grouped setae have lost most of their functional activity owing to the absence of otoliths. The thread setae are, undoubtedly, the most important sensory organs of the otocyst. (For a further discussion of this subject the reader is referred to the paper by Prentiss.)

The sensory setae of Cancer are of two kinds.

The **tactile setae** may be present in various parts of the body. They are found on the antennules and antennae, and on most of the appendages. The setae of the otocysts are probably modified tactile setae. They are characterised by having a long tapering shaft which bears barbs, and each seta is innervated by a single nerve fibre and a single nerve cell.

The **olfactory setae** (fig. 74) are short and blunt, and are much more firmly attached to the integument than the tactile setae. Each seta is divided into proximal and

distal portions by a transverse suture. At the distal end the seta is either perforated or the membranous covering is extremely thin. The olfactory setae differ from the tactile setae in having numerous nerve elements for each seta. They are present on the exopodite of the antennule on the side opposite to the long setae. They are extremely small, and there are only one or two on each ring of the exopodite. On the endopodite of the antennule there are also a few small setae on the dorsal side of each ring, which have the appearance of olfactory setae. The gustatory setae present in the region of the mouth are modified olfactory setae.

## REPRODUCTIVE ORGANS

(Plate XII).

### 1. MALE (fig. 78).

The abdomen is much narrower than in the female, and the third, fourth and fifth abdominal somites are fused together. Abdominal appendages are present only on the first and second abdominal somites, and these are modified to form copulatory organs. The external genital apertures are paired, and each is situated at the tip of a membranous papilla on the ventral side of the coxopodite of the last walking leg. The thoracic sterna are deeply concave, in order to receive the closely-applied abdomen. The locking apparatus of the male abdomen is much better developed than in the female. The dorsal side of the carapace is much flatter in the male than in the female. As Williamson has pointed out, the lobed antero-lateral border of the carapace is slightly turned up in mature males. The chela of the mature male are larger than those of mature females of the same size.

The two abdominal appendages of each side form a

single copulatory organ (see fig. 16). The anterior appendage (*p.* 1) is tubular, and into the tube the posterior rod-like appendage (*p.* 2) is inserted during copulation. The copulatory organ of each side is introduced into one of the vulvae of the females during fertilisation. The genital papillae of the male are too short to reach the vulvae, and the abdominal appendages have become modified to form sexual organs in consequence of this. During copulation each genital papilla fits into the base of the tubular appendage and the spermatophores are poured into the tube. The rod-like second appendage is constantly working up and down the tube, and thus forces the male sexual products into the spermatheca of the female.

The **testes** (*test.*) are paired and symmetrical, and the two halves are connected immediately behind the fore-gut. Each testis is a compact lobulated organ situated in the antero-lateral region of the cephalothorax. It is superficial in position, and lies immediately below the dermis and above the digestive gland. The size and shape of the testis varies considerably according to the condition of the animal. In immature crabs it may be extremely small, but in the mature specimens the testis is massive and lobulated, and may cover almost the whole of the digestive gland. Its blood supply is obtained from the large spermatic branch of the lateral artery. At its inner extremity, near the cardiac fore-gut, each testis is connected with the vas deferens (*v. d.*). The main part of the testis gives off a posterior branch which passes backward beneath the vas deferens alongside the mid-gut caecum. Above the mid-gut this prolongation turns inward and joins with the similar portion from the other side to form a bridge behind the pyloric fore-gut.

The *vasa deferentia* are a pair of long convoluted



tubes passing backward from the testes to the posterior region of the thorax, where each opens to the exterior on the coxopodite of the last walking leg.

In a mature crab the course of each of the vasa deferentia is as follows:—Where it arises from the inner portion of the main lobe of the testis the vas deferens is an extremely convoluted and narrow tube. As it sweeps round the outer side of the cardiac stomach the tube grows broader and the convolutions become less complicated, so that in this region the course of the vas deferens may be traced without much difficulty. At the level of the pyloric fore-gut the duct turns suddenly inwards and covers the lateral walls of this region of the alimentary canal. From this point the vas deferens passes backward as a white convoluted tube above the hind-gut and below the pericardium. The maximum width is attained below the anterior region of the heart. Behind this point the duct gradually becomes narrower, and is then known as the *ejaculatory duct* (*e. d.*). At the posterior end of the pericardium the duct dips downward through the foramen on the outer side of the “*sella turcica*.” It then passes behind the dorsal extensor muscle of the coxa of the last walking leg and in front of the extensor muscle of the basi-ischium of the same appendage. Below the latter muscle it passes beneath the flexor of the basi-ischium, and opens to the exterior at the end of a soft papilla situated on the ventral surface of the coxa of the last walking leg.

In sections through the testis the gland is seen to be composed of numerous follicles which are closely packed together. Each follicle is lined by epithelial cells which surround a central cavity, and this cavity is continuous with that of the vas deferens. In an early stage the cells of the follicles are not differentiated and are quite small.

Eventually some of these become spermatoblasts and increase greatly in size. Each spermatoblast gives rise to a large number of spermatozoa. In sections through a mature testis it is difficult to distinguish the follicles, as the cavities of the latter become almost obliterated by the growth of the spermatoblasts. When the spermatozoa are ripe they break free and are carried down into the vas deferens. Here they become collected together in small groups, and each group becomes surrounded by a capsule to form a *spermatophore*.

The spermatozoa (fig. 81) are non-motile. They consist of a central dark portion containing a nucleus and an outer clear margin. In side view the clear margin is seen to be much thinner than the central part of the cell, and has the appearance shown in fig. 81. The diameter of the cell is about  $6\mu$ .

The presence of the spermatophores gives rise to the white appearance so characteristic of the vasa deferentia of mature male crabs. In small immature crabs the vas deferens is narrow and almost transparent, due to the absence of spermatophores. As pointed out by Williamson, "the condition of maturity in the male is the presence of ripe male elements in the vas deferens." It is probable that most male crabs above  $4\frac{1}{8}$  inches in width are mature, although Williamson has given instances of male crabs attaining maturity at a much smaller size.

## 2. FEMALE (fig. 77).

The abdomen is broad, and all the somites are freely movable. There is one pair of appendages on each of the second, third, fourth and fifth somites. After the ova are spawned they are attached to the endopodite setae of the abdominal appendages. The external genital apertures

are a pair of large openings situated on the sternum of the sixth thoracic somite. The thoracic sterna are not so concave as those of the male, and the abdomen is not so closely applied to the thorax. The abdominal locking apparatus is poorly developed. The dorsal side of the carapace is well arched in the mature females, and the antero-lateral border of the carapace is not upturned as in the males.

The **ovaries** (*ov.*) are paired, and lie in a similar position to the male reproductive organs. There is, however, a considerable posterior prolongation of each ovary. As in the male, the two antero-lateral portions are connected behind the pyloric fore-gut by a strand of gonadial tissue, which forms a bridge over the mid-gut. Behind this transverse connection each ovary is prolonged backward as a narrow strip, which extends to the extreme posterior end of the thorax. At the posterior extremity the two prolongations fuse together in mature specimens. These backward extensions of the ovaries occupy a similar position to the vasa deferentia of the male; that is to say, they lie above the hind-gut and below the pericardium. Beneath the anterior end of the latter each posterior branch is connected on its outer side with a large sac, the *spermatheca*\* (*spt.*). Each spermatheca is continued into a short *oviduct* (*ovd.*), which opens to the exterior by means of the vulva on the sternum of the sixth thoracic somite.

The condition of the ova in the ovary naturally depends upon the degree of maturity attained by the gonads. The immature gonads are small and pale, and no evidence of the presence of eggs can be detected by the naked eye. The mature gonads, however, fill almost the

\* In young crabs the spermatheca is extremely small, and can only be made out with difficulty.

whole of the dorsal side of the cephalothorax. They are of an orange-red colour, and the separate eggs can be readily distinguished. The red colour is due to the presence of the food-yolk. The yolk granules form the main part of the mature ovum (fig. 79). With regard to the condition of the ovaries between two processes of ecdysis, the reader is referred to the section on Bionomics.

Copulation takes place immediately after the female has cast, and while it is still in a soft condition. Apparently the spermatozoa burst free from the spermatophores as soon as they leave the vas deferens. In the spermatheca only free spermatozoa are found. After copulation the cells lining the spermatheca secrete a fluid which fills the cavity of the oviduct. This secretion hardens upon contact with the sea water, and thus the oviducts become effectively plugged, and the contents of the spermatheca cannot escape. It is a remarkable fact that the spermatozoa remain inside the spermatheca for many months before they fertilise the ova.

The eggs are spawned in the winter. Upon reaching the exterior, each egg is probably surrounded by two membranes—an inner vitelline membrane and an outer chorion. Between the two is a perivitelline space, which, according to Williamson, contains a fluid possessing adhesive properties. The eggs become attached to the endopodite setae of the abdominal appendages. The interesting question regarding the mode of attachment of the eggs to the endopodite setae is not yet conclusively settled. Some of the early observers believed that a sticky substance was secreted around the eggs as they were being shed. This, however, would not explain why the eggs become attached only to the endopodite setae. Herrick's\* explanation is that the tegumentary glands of

\* Herrick. "The American Lobster," *Bull. U.S. Fish Com.*, 1895.



the endopodites of the pleopods secrete an adhesive fluid. Williamson\* gives a detailed explanation of the method of attachment. He suggests that the endopoditic seta penetrates the chorion of the egg in two places, and thus the egg becomes skewered on the seta. The piercing of the chorion liberates the adhesive perivitelline fluid, which assists in making the attachment more permanent. The chorion eventually becomes drawn out at the point of attachment, and the egg appears to be attached to the seta by a stalk (see fig. 80).

According to Williamson, the number of eggs attached to the abdomen may vary from half a million in a small mature female to three millions in a large crab.

#### DEVELOPMENT.

It is a surprising fact that the development of *Cancer pagurus* has never been satisfactorily investigated. The internal changes do not appear to have been followed in any Brachyurous embryos, and although the general characters of the larval developments in the Brachyura are well known, our knowledge of these stages in *Cancer pagurus* is extremely scanty.

The development may be divided into three stages—embryonic, larval and post-larval.

The embryonic development takes place while the embryo is attached to the pleopods of the female, and, therefore, extends over a period of about seven months. The internal development during this period has not been investigated, but it is very probable that the Brachyura do not differ from the Macrura in this respect. The early development has been thoroughly investigated in the Macrura.†

\* Williamson. 23rd Report, Scotch Fishery Board.

† See Herrick, F. H. "The Development of the American Lobster," *Johns Hopkins Univ. Circ.*, Vol. IX, 1890, No. 80.

Reichenbach, H. "Studien zur Entwicklungsgeschichte des Flusskrebses," *Ab. Senkenberg. Nat. Ges. Frankfurt*, Bd. XIV, 1886.

While working at the Biological Station, Heligoland, I was able to examine the early larval stages of Cancer. I was fortunate enough to obtain berried crabs on which the embryos were ready for hatching. The process of hatching lasted several hours, and during this time the crab assisted by moving its abdomen backwards and forwards. The last walking legs were also used for the purpose of detaching the larvae from the pleopods. Unfortunately, I was not successful in keeping the larvae alive longer than the first zoëa stage.

I give below a summary of the characters of the larval stages of the Brachyura in general. I have utilised the results of other investigators,\* and have also added my own observations. The larval stages may be divided into Protozoëa, Zoëa (four kinds) and Megalopa.

**Protozoëa** (Pl. XIII, figs. 83, 84). Hatching takes place at this stage, which is of very short duration. There are no frontal or dorsal spines present. The lateral spines (*sp. l.*) are present one on each side of the cephalothoracic shield. The large paired eyes are present in the head. The abdomen is well defined, but only five somites and the telson can be distinguished. The sixth somite is at this stage fused with the telson. The telson is forked, and each branch bears strong spines (fig. 84). All the cephalic and the first two pairs of thoracic limbs are present. The antennule is blunt and consists of two segments, of which the distal is the larger. The antenna consists of a broad basal joint, from which is given off a short pointed process. The mandible is a small rounded outgrowth. The first and second pairs of maxillae are

\* Williamson, H. C. "On the Larval and Early Stages and Rate of Growth of the Shore Crab (*Carcinus maenas*)," *Twenty-first Annual Report, Fishery Board for Scotland*, p. 136.

Korschelt and Heider. *Text Book of Embryology* (Invertebrates, Part II).

similar, and are beginning to show evidences of a biramose structure. The first and second pairs of maxillipedes are large and biramose. The protopodite is large. The endopodite and exopodite have few setae. Towards the end of the protozoëa stage the cuticular covering becomes very loose, and beneath can be seen the developing organs of the first zoëa stage. Chromatophores are present at the sides of the body.

**First zoëa** (Pl. XIII, figs. 85, 86, 87). This stage is generally seen about three or four hours after hatching, and probably lasts for at least ten days. The important difference between this and the previous stage is the presence of the large frontal and dorsal spines. The latter is about half as long as the body, and the frontal spine is about two-thirds the length of the body. Both are tipped with a red pigment. The lateral spines are well developed. The branched chromatophores are well developed. The number of appendages appears to be the same as in the previous stage, but they are more highly developed. Each antennule bears a group of setae at its tip. The antennae and both pairs of maxillae are biramose. The exopodites of the maxillipedes each bear four long setae. The third maxillipedes and the pereopods and the associated gills are present as extremely small buds, which are hidden beneath the cephalothoracic shield. The pleopods may be seen for the first time as extremely small tubercles. In some examples of both the protozoëa and the first zoëa there was a pair of tubercles present on the second abdominal somite. The telson differs from that of the previous stage in having two extremely long posterior branches.

**Zoëa stages II, III and IV.** I have not been able to identify these stages in *Cancer pagurus*, but in *Carcinus maenas* they have the following essential characters. They

are very similar to the first zoëa in appearance. Between the two branches of the antenna an outgrowth takes place in the second stages, and ultimately develops into the long flagellum. The maxillae are not very different from those of the first stage. The setae on the exopodites of the first and second maxillipedes increase in number at every stage. The last six pairs of thoracic appendages and their gills gradually increase in size, but never become functional during the zoëa stages. The pleopods gradually develop until at the fourth stage there are five pairs present. There is not a pair present on the sixth abdominal somite in *Carcinus*. At the third stage the sixth abdominal somite becomes separate from the telson. The rostral and dorsal spines gradually become shorter.

In his account of the larval stages of *Cancer irroratus*, Smith\* describes the following characters in the last zoëa stage:—Rostral and dorsal spines short. The abdominal legs are seen as stumpy outgrowths. The third maxillipede is well developed, but the other posterior thoracic appendages do not project below the edge of the cephalothoracic shield. The flagellum of the antenna is present.

**Megalopa stage.** The main points of difference between the zoëa and megalopa are as follows:—The frontal and lateral spines disappear. According to Smith, the dorsal spine of *Cancer irroratus* persists as a small backwardly-projecting process. The carapace is broader. The pereopods are well developed, and the gills are probably functional. The pereopods are never biramous as in the *Macrura*. The abdomen is macrurous, and the pleopods are used for swimming. The telson is much shorter, and loses its spines. The megalopa is still a pelagic stage. Its pereopods, however, may be used for

\* Smith, S. "The Invertebrate Fauna of Vineyard Sound," *U. S. Fish Commission Report*, 1871-72 (published 1873).



walking on the bottom. The last pereopod in *Carcinus maenas* and *Cancer irroratus* has a tuft of setae on the dactylos. According to Smith, the megalopa stage is very short, and at the first moult it changes into a young adult.

**Post-larval stages.** The young adult differs from the megalopa in having the abdomen tucked beneath the thorax. It is no longer a pelagic animal, but lives on the bottom, and uses the last four pairs of pereopods for the purposes of locomotion. As pointed out by Smith\* and Cunningham,† the early post-larval stages differ considerably from the larger specimens. The carapace is elongated and the rostral region is well developed. The lobes of the antero-lateral border are sharp. Cunningham pointed out that it is difficult to distinguish the early stages of *Cancer* from those of *Atelecyclus heterodon*. At each succeeding moult the transverse axis of the carapace increases more rapidly than the longitudinal axis.

### ECONOMICS AND BIONOMICS.‡

The main features in the life-history of the edible crab may be briefly summarised as follows:—

*Cancer pagurus* is found all round the coasts of the British Isles, being especially abundant on the rocky coasts. The size at which maturity is attained is variable, but most crabs above five inches in breadth may be said to be mature. There appear to be no records of large

\* Smith. *Op. cit.*

† Cunningham, J. T. "On the Early Post-larval Stages of the Common Crab (*Cancer pagurus*), and on the Affinity of that species with *Atelecyclus heterodon*," *Proc. Zool. Soc.*, 1898, Part II, p. 204.

‡ For further information on these subjects see—

Cunningham. *Cornwall County Council: Report of the Executive Committee for Fisheries*, 1897-8. Penzance, 1898.

Williamson. *Fishery Board for Scotland: 18th, 22nd, and 23rd Annual Reports.*

Wilson, *Northumberland Sea Fisheries Committee: Reports on*

edible crabs, but I have seen several specimens in shops having a carapace breadth of about twelve inches. A crab measuring nine inches would be considered a large one. The crabs are captured by means of crab-pots ("creels," Williamson; "creaves," Wilson), which are baited with fish. In Port Erin the chief fishing season is from March to September, but the crab fishery is continued throughout the winter. Generally speaking, the chief fishing season in the British Isles lasts from the early spring to the autumn. In some districts, such as the North-East of England, there is a close season.

Fishermen are not allowed to sell crabs below four and a half inches, berried crabs or soft crabs, but these restrictions do not hold good concerning crabs used for bait. Since, in some parts of the country, crabs are used for bait to a large extent, these laws for the protection of the crab fishery to some extent fail in their purpose. The size limit may be increased at the discretion of the local committees. In the Lancashire District the minimum size is five inches.

In the summer the mature crabs frequent the inshore waters, and in the winter they occur in the deeper off-shore waters. The immature crabs do not take part in this annual migratory cycle. The mature crabs cast in the autumn, and the females are fertilised when "soft." Spawning takes place in the deeper water in winter. The larvae are hatched in the following summer in the inshore waters. Wilson is of the opinion that the "berried"

*the Crab Fishery*, 1893 and 1895. Also *Proc. R. Soc. Edin.*, Vol. XX, 1894, p. 309.

Meek. *Northumberland Sea Fisheries Committee*, 1897-1906.

Buckland, Walpole and Young. *Reports on the Crab and Lobster Fisheries of England and Wales, of Scotland, and of Ireland* [C. 1695], 1877, p. 56.

Statistics regarding the crab fishery may be obtained from the various Annual Reports of Inspectors, Sea Fisheries (England and Wales).

crabs feed very little, and he records instances of such crabs being covered with sand. Williamson's observations appear to support this statement.

Baudouin\* gives an interesting account of how the phenomenon of autotomy is utilised by the fishermen of Southern Spain. The common edible crab of that region is *Gelasimus tangeri*. When the crabs are captured the large claws are removed up to the fracture plane, and the crab is put back in the water. Only the claws are sent to market, the crab being returned to the sea to grow new ones.

The statistics published annually by the Fishery Inspectors for England and Wales are very scanty, and appear to have but little value in the elucidation of the numerous problems connected with the natural history of the edible crab.

I give below a summary of the figures published in the Annual Reports of the Fishery Inspectors for England and Wales since 1887, merely giving the total number of crabs caught in each year and their approximate value.

Year.	Total Number.	Approximate Value.
1887-1897 (average)	4,669,861	£55,082
1898 .....	5,628,114	£67,895
1899 .....	4,918,184	£62,494
1900 .....	5,177,350	£56,822
1901 .....	5,325,974	£58,743
1902 .....	—	—
1903 .....	4,923,536	£54,327
1904 .....	4,580,318	£52,556
1905 .....	5,106,345	£59,479
1906 .....	—	—

\* Baudouin, M. "Utilisation de l'autotomie chez un Crabe." *Revue scientifique* (Ser. V), T. VI, No. 10.

Through the kindness of Dr. Jenkins, Superintendent of the Lancashire and Western Sea Fisheries District, I am able to give the following statistics dealing with crabs landed in that Sea Fisheries District during the years 1900 to 1906, inclusive:—

Year	New Quay.		Aberdovey.		Pwllheli.		Holyhead.		Liverpool.	
	No.	£'s.	No.	£'s.	No.	£'s.	No.	£'s.	No.	£'s.
1900	—	—	—	—	6,000	180	600	6	—	—
1901	—	—	—	—	2,000	60	800	8	—	—
1902	—	—	—	—	10,204	112	1,100	11	—	—
1903	—	—	—	—	11,143	135	1,000	11	600	5
1904	50	1	—	—	10,710	125	615	6	900	8
1905	40	2	—	—	8,851	109	760	8	466	6
1906	509	11	435	7	9,347	113	—	—	800	8

The crabs returned as having been landed at Liverpool were certainly not caught in that District.

The Harbour Master of Port Erin has kindly provided me with the following figures, which give the number of crabs captured by the Port Erin fishermen during the years 1904-5-6:—

	1904.	1905.	1906.
January .....	?	800	1,200
February .....	?	3,400	2,200
March .....	7,000	6,500	4,000
April .....	7,500	8,000	6,500
May .....	7,500	9,400	7,000
June .....	6,100	5,000	4,000
July .....	7,000	6,500	7,000
August .....	6,000	2,000	5,500
September .....	3,000	2,000	2,500
October .....	1,600	1,500	2,500
November .....	500	400	300
December .....	1,200	800	300
Total .....	47,400*	46,300	43,000

\* The figures for January and February are not given.



## Fishery regulations.\*

In section 8 of the Fisheries (Oysters, Crabs and Lobsters) Act (40 & 41 Vict. ch. 42), the following restrictions are imposed:—

A person shall not take or sell:—

(1) Any edible crab which measures less than four inches and a quarter across the broadest part of the back.

(2) Any edible crab carrying spawn.

(3) Any edible crab which has recently cast.

Such crabs may, however, be used for bait.

In the Lancashire and Western Sea Fisheries District the minimum legal size has been raised to five inches. (Bye-law 25*b*: "No person shall remove from a fishery any edible crab measuring less than five inches across the broadest part of the back.")

## Size of crabs at maturity.

*Female*.—There appears to be some difference of opinion with regard to the size at which the female becomes mature. Wilson† had reason to believe that on the Northumberland Coast the size of maturity is about six inches. Williamson's‡ investigations, on the other hand, show that the crabs of the east coast of Scotland become mature when about four and a half inches in width. I have examined crabs from Port Erin which had been fertilised when about this size. It is probable that a crab is mature when it has attained a size of four and a half inches, but in many cases fertilisation may not be effected until after the next casting. There is no

\* For a discussion on this subject read Williamson, 18*th Annual Report*, p. 134. Other literature on this point is given by him on p. 78 of the same report.

† Wilson. *Northumberland and Sea-Fisheries Committee*, 1893 1895; *Proceedings Royal Society, Edinburgh*, 1892-3, p. 309.

‡ Williamson. *Eighteenth Report*, p. 77.

doubt that many crabs do not bear their first batch of eggs until attaining a size of six inches.

*Male.*—The male crabs evidently attain maturity at a smaller size than is the case in the females. Probably all males above four and a half inches are mature, and Williamson has found mature males below this size.

Fertilisation takes place in the inshore waters during the late summer and autumn, and is effected immediately after the female has cast. The one supply of spermatozoa is probably sufficient for two successive batches of eggs, and even three in the older crabs. The spermatozoa remain in the spermathecae, and the entrances to the latter are closed by plugs, which are probably formed by a secretion from the walls of the spermathecae which hardens in contact with water.

The spawning of the eggs is effected in the deeper offshore waters during the winter. The eggs are attached to the endopoditic setae of the pleopods, and remain there until the following summer, when they are hatched in the inshore waters.

The crab probably does not cast after the larvae are hatched, but a second batch of eggs are spawned in the following winter in the offshore waters. As with the first batch, the developing embryos will be retained on the abdominal appendages until the following summer, when the hatching process will again take place in the inshore waters. After the second hatching the female probably casts, and is fertilised.

The developing embryos probably remain attached to the pleopods for about seven months. The various zoëa stages and the megalopa stage may extend over a period of two months, but our knowledge of the larval stages of *Cancer* is remarkably scanty. It is probable that the larvae hatched at the end of June will be in the first adult stage about the end of August.

## DISTRIBUTION AND MIGRATION.

According to Williamson,\* the crabs after the larval stages may be placed in four different groups according to their distribution.

*Group I* includes the young stages up to  $\frac{7}{8}$ -inch in breadth. These are probably restricted to the shallow shore waters.

*Group II* includes the crabs found on the beach between tide-marks. From  $\frac{7}{8}$ -inch to  $2\frac{1}{4}$  inches in breadth.

*Group III* includes the crabs living in the littoral waters beyond low-water mark. From  $2\frac{1}{4}$  to 4 inches.

*Group IV* includes all the crabs above 4 inches in breadth. These crabs are mostly mature, and migrate from the inshore waters in the summer to the deeper offshore waters in the winter.

With regard to Group I, my own observations confirm those of Williamson. In the spring and summer, when small specimens of *Cancer* must be very abundant, they are very rarely found between tide-marks. On the other hand, they are frequently taken in the dredge close to the shore.

The migration of the mature crabs has been long known to fishermen, and our knowledge with regard to this subject is now fairly complete, thanks to the work of Williamson, Meek and others. Only the crabs of Group IV are concerned in the migration, which may be divided into an offshore migration in the autumn and an inshore migration in the spring. Both hard and soft crabs begin to move outward into the deeper water in September (see Text fig. 13). The extreme depth to which they travel must necessarily vary with the locality, but it is generally between twenty and thirty fathoms.

\* Williamson. *Eighteenth Annual Report*.

The crabs probably stay in the offshore waters from December to February, and it is here that the females spawn. The inshore migration begins in February, and in May the bulk of the crabs are probably back in the inshore waters again. The hatching of the larvae takes place in the warm inshore waters, and casting process is performed, and, in the case of the females, fertilisation is effected immediately after ecdysis. In the autumn the offshore migration again commences, and the cycle is repeated.

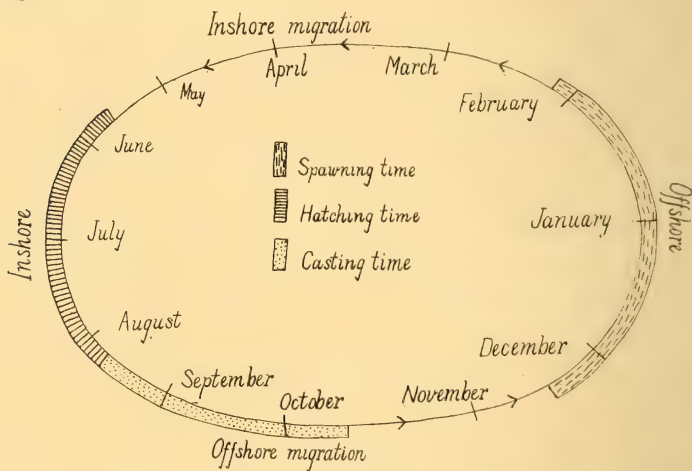


FIG. 13.—Diagram illustrating the annual migratory cycle of mature crabs. The three processes—casting, spawning and hatching—probably do not take place in one cycle.

It must be remembered, however, that in the mature female crab casting and fertilisation in the autumn is not necessarily followed by spawning in the same winter. Furthermore, casting will only take place once in two or three years. But when spawning does take place it is in the offshore waters, and the hatching is always in the inshore waters.

As suggested by Williamson, the main reason for



this regular migration is the influence of temperature. In the winter the deeper layers of the offshore waters are warmer than the inshore waters, and hence the former are most suitable for the spawning time. In the summer the shallower inshore waters become much warmer, and here the young larvae are hatched. It is also reasonable to suppose that the warm water of the inshore regions is specially favourable for the somewhat critical period of casting. The necessity for food may also have an important bearing on the yearly migration.

I give below a summary of the life-history of an adult female crab between two successive processes of ecdysis. The condition of the gonads at the various stages is discussed. In the example given, it is assumed that the crab did not spawn in the winter following fertilisation. The period elapsing between fertilisation and the first spawning appears to depend altogether on the condition of the gonads. As a rule, the ovary is very small and pale when ecdysis takes place, and in such a circumstance the eggs cannot possibly be ready for spawning in the course of three or four months. Consequently the eggs are not shed until the second winter, i.e. fourteen months after fertilisation. In some crabs the ovary is fairly ripe when ecdysis takes place, and in such cases the eggs will probably be extruded in a few months.

**First Year. September**—*The crab casts and is fertilised.*

It then migrates to offshore waters for the winter. It returns to inshore waters in the spring of the second year. In the following autumn offshore migration again takes place.

**Condition of ovary.** At first it is poorly developed and pale in colour, and the eggs are without food-yolk. The ovary gradually ripens, first becoming

pink in colour and finally a bright orange. This change in colour is due to the development of food-yolk. The eggs first become yolked in the spring of the second year.

**Second Year. December**—*Eggs extruded (first spawning).*

When the spawning takes place the crabs are in the deeper offshore waters. In the spring of the third year the inshore migration commences.

**Condition of ovary.** Immediately before spawning the eggs are large and of a bright orange colour, due to the food-yolk. After the extrusion of the eggs the ovary is shrunken and of a pale colour. The majority of the eggs are small and without food-yolk. There may be, however, a few ripe eggs present which have failed to escape to the exterior. As the spring advances the eggs gradually become more mature, and present a pinkish colour.

**Third Year. July**—*First hatching takes place.*

In the autumn of the third year the offshore migration again takes place.

**Condition of ovary.** At the time of the first hatching the ovary is generally of a red colour, and the eggs are about half ripe.

**Third Year. December**—*Eggs extruded (second spawning).\**

During spawning time the crab is in the offshore waters. In the spring of the fourth year the inshore migration commences.

**Condition of ovary.** Very similar to the appearance at the time of the first extrusion.

**Fourth Year. July**—*Second hatching takes place.*

The crab is now in the inshore waters.

\* Williamson gives instances in which the second spawning did not take place for about fifteen months after the first hatching. It is difficult to say whether this is of regular occurrence.

**Condition of ovary.** During the spring and summer the ovary remains unusually small, and has a pale colour. The eggs are mostly small and without yolk.

**Fourth Year. September—***The crab casts and is fertilised.*

During these processes the crab is in the inshore waters. Immediately after fertilisation the offshore migration will commence, and the whole of the above history will be repeated.

**Condition of ovary.** Similar to that at the first casting.

#### BIONOMICS OF ECDYSIS.

As already seen, the growth of the crab can only take place by the exuviation of hard shell or exoskeleton. Immediately after ecdysis has taken place the body—now covered by a soft flexible membrane—increases considerably in size. In the mature female fertilisation is also effected while the crab is soft. The soft crabs are not fit for food, and it is illegal to expose them for sale when in this condition.

#### Season of casting.

The young crabs cast at various times of the year, but after the third year ecdysis generally takes place in the autumn. According to Williamson, the main casting period on the East Coast of Scotland is from July to September, but it may be extended to December. From August to November appears to be the chief casting time in the Isle of Man. The casting is effected in the warmer inshore waters. The hardening process in the mature crab lasts from three to five months, according to Williamson.

### Rate of Growth.

From the evidence obtained by Williamson and Waddington, and also from observations taken in the course of the present work, it would appear that the rate of growth varies considerably. For example, in a series of seventeen crabs measured in Heligoland I found that the fraction of increase varied from  $\frac{1}{2.5}$  to  $\frac{1}{5.8}$  (see table on p. 475). In Waddington's series published by Williamson\* the fraction varied from  $\frac{1}{2}$  to  $\frac{1}{6.5}$ , and in the table published by Williamson† the ratio of increase varies from  $\frac{1}{3.1}$  to  $\frac{1}{9}$ . But, speaking generally, it may be said that this ratio is between  $\frac{1}{3}$  and  $\frac{1}{4}$ .

It is not surprising that this rate of growth should be a variable one. The main factors to be considered are probably the general health of the animal (i.e. the condition of the tissues) the amount of food, the purity of the water and the temperature of the water, and many other causes. Any one of these factors would alone be capable of affecting very considerably the rate of growth.

I give a table (p. 475) showing the rate of increase in seventeen different crabs. These measurements were taken from specimens in the Nordsee Museum, Heligoland, by kind permission of the Director, Professor Heincke.

### Frequency of casting.

Speaking generally, it may be said that in the younger stages the moultings are frequent, but that as the crab grows older the period between each process of ecdysis and the next becomes longer.

In the earliest stages the frequency of casting differs in

\* Williamson. *Twenty-second Annual Report, Fishery Board for Scotland*, p. 135.

† Williamson. *Eighteenth Annual Report, Fishery Board for Scotland*, p. 110 (see also *Twenty-second Report*, p. 122).



a marked degree in individuals of the same approximate age. As stated above, the hatching period lasts from

	Carapace breadth before casting. Cm.	Carapace breadth after casting. Cm.	Ratio of Increase.
1	1.55	2.05	$\frac{1}{3.1}$
2	2.15	2.80	$\frac{1}{3.3}$
3	2.25	2.95	$\frac{1}{3.2}$
4	3.10	4.12	$\frac{1}{3.0}$
5	3.12	3.82	$\frac{1}{4.4}$
6	3.40	4.58	$\frac{1}{2.8}$
7	4.00	5.25	$\frac{1}{3.2}$
8	4.25	5.50	$\frac{1}{3.4}$
9	4.45	5.55	$\frac{1}{4.0}$
10	4.56	5.70	$\frac{1}{4.0}$
11	5.20	6.60	$\frac{1}{3.7}$
12	5.55	6.50	$\frac{1}{5.8}$
13	5.55	7.20	$\frac{1}{3.3}$
14	5.70	7.20	$\frac{1}{3.8}$
15	6.50	9.10	$\frac{1}{2.5}$
16	7.80	9.75	$\frac{1}{4.0}$
17	12.80	15.50	$\frac{1}{4.7}$

June to August. The "early" larvae, therefore, will have a considerable advantage over the "late" larvae.

Consequently, the early crabs will probably cast eight or nine times before the following summer, while the late crabs may have cast only five times. There will, also, be a corresponding difference in size.

It will be realised, therefore, that it is quite impossible to state the age of a crab with any degree of certainty. The size of the crab not only depends upon the frequency of casting, but also upon the ratio of increase at each act of ecdysis. As we have already seen, both these factors are subject to a considerable amount of variation. The most valuable information on this point is to be obtained from continued observations of crabs kept in an aquarium. This has been done to a certain extent by Mr. Waddington, of Bournemouth. But, even in such cases, we are not justified in establishing any broad principles on the results obtained. In the first place, there is no doubt that captivity affects the frequency of casting. There is also the same difficulty that obtains amongst crabs living amongst natural conditions, viz., that ratio and frequency of casting vary in individual crabs. This is demonstrated quite clearly by an examination of Waddington's\* three series, in which both factors vary considerably.

But in spite of the impossibility of forming any definite laws with regard to the frequency of casting, a careful examination of all the available facts and figures enables one to give a general outline of the life-history of Cancer with regard to this particular point.

I propose, therefore, to give such an outline, but, in doing so, I must emphasise what I have already said—that we are dealing with factors which are by no means constant.

I intend taking a purely hypothetical case, utilising,

\* Williamson. *Twenty-second Annual Report*, p. 135.

however, the stages of Waddington's Series A for the first two years.

**First year.** The larva was probably hatched in June. During the first year the crab cast eight times, and at the end of the first year (June to June) it was 30.75 mm. broad.

**Second Year.** The crab cast twice (September and March), and was 45.75 mm. broad at the end of its second year. (In the first two years the ratio of increase varied considerably. It will also continue to vary throughout life, but for practical purposes I intend taking the ratio of increase to be uniformly  $\frac{1}{4}$ , which is an average ratio.)

**Third year.** There will probably be two castings, so that at the end of the year the crab will be 70.6 mm. broad.

**Fourth year.** There will be only one ecdysis. At the end of the year the crab will be 88 mm. broad.

**Fifth year.** Only one casting. Size at the end of the year, 110 mm. The crab will now be mature, and if a female will probably be fertilised while in the "soft" condition.

**Sixth year.** The crab will not cast.\*

**Seventh year.** The crab will cast once, and will be 137.5 mm. in width after ecdysis. Fertilisation will again be effected when the crab is "soft."

**Eighth year.** The crab will not cast.

**Ninth year.** The crab will cast, and after ecdysis will be 171.8 mm. broad. Fertilisation will take place immediately after ecdysis.

I believe it to be highly probable that after the female crab attains a size of six inches (150 mm.) ecdysis will only take place once in three years (see below under

\* There is every reason to believe that after attaining maturity the crabs only cast once in two years.

"Granny" Crabs). If a male, it will probably cast once in two years.

## FIRST YEAR.

Number of Casting ...	1	2	3	4	5	6	7	8
Width in mm. ....	4.75	5.75	8.5	10.75	14.5	19.5	24.5	30.75
Width in inches .....	( $\frac{1}{3}$ )	( $\frac{1}{4}$ )	( $\frac{1}{3}$ )	( $\frac{2}{5}$ )	( $\frac{3}{5}$ )	( $\frac{4}{5}$ )	(1)	( $1\frac{1}{4}$ )

## SECOND YEAR.

## THIRD YEAR.

Number of Casting .....	9	10	11	12
Width in mm. ....	36.5	45.75	56.5	70.6
Width in inches .....	( $1\frac{1}{2}$ )	( $1\frac{3}{4}$ )	( $2\frac{1}{4}$ )	( $2\frac{3}{4}$ )

## FOURTH YEAR.

## FIFTH YEAR.

## SIXTH YEAR.

Number of Casting	13	14	Did not cast
Width in mm. ....	88.2	110.0	—
Width in inches .....	( $3\frac{1}{2}$ )	( $4\frac{1}{2}$ )	—

## SEVENTH YEAR.

## EIGHTH YEAR.

## NINTH YEAR.

Number of Casting	15	Did not cast	16
Width in mm. ....	137.5	—	171.8
Width in inches .....	( $5\frac{1}{2}$ )	—	( $6\frac{3}{4}$ )

## TENTH YEAR.

## ELEVENTH YEAR.

## TWELFTH YEAR.

Number of Casting	Did not cast	Did not cast	17
Width in mm. ...	—	—	214.7
Width in inches ...	—	—	( $8\frac{1}{2}$ )

The approximate calculations given above do not lend support to Williamson's statement that "a crab of four and a quarter inches across would be not less than three years, nor probably more than four years old." Even if we take a growth ratio of one-third, which is rather high, we find that the crab would not reach the



size of four and a quarter inches until the fourth year at the earliest.

There is abundant evidence to show that the adult male and female crabs do not cast every year, but probably only once in two years. There appears to be little doubt, moreover, that in the older crabs ecdysis may take place less frequently than once in two years, and Williamson has given several instances of crabs in which the shell is undoubtedly more than two years old. In the Nordsee Museum, Heligoland, there is a female Cancer, with a carapace breadth of 17 cm., having attached to the shell, an Anomia 5.8 cm. in width.

Although there appears to be a stage in the life-history of Cancer after which ecdysis is only triennial, no attempt has been made to determine at which period the change from a biennial to a triennial growth takes place.

Such an investigation presents innumerable difficulties, and the only way in which the problem can be satisfactorily solved is either by having large crabs under observation in captivity for many years, or by the careful analysis of a great number of exact measurements made for the purpose. Neither of these methods has been followed, and although Williamson has been able to gather a mass of extremely useful information, his statistics do not appear to be of much value in the elucidation of this particular problem.

Our present knowledge with regard to the frequency of casting may be briefly summarised as follows. In the early stages the young crab casts frequently. As it grows older the periods between successive castings become longer, and it is probable that after reaching maturity both males and females cast only once in two years. There is scattered evidence to show that many large crabs

cast less frequently than once in two years, and a stage is ultimately reached when the crab ceases to cast.

It is my belief that after attaining a size of about six inches carapace breadth the females, as a general rule, only cast once in three years, but that the males continue to cast biennially for a considerably longer period. It must be admitted that the figures on which this suggestion is based are not sufficiently large to warrant any conclusive statements on the subject. So that, although I feel that my explanation is a reasonable one, and is, furthermore, supported by many facts, I bring it forward merely as a provisional hypothesis. I further recognise that, just as in the case of the younger stages, there can be no rigid law regarding the frequency of casting. It is quite possible that many males over six inches cast less frequently than once in two years, and that many females above this size may cast biennially.\*

#### *“Granny” Crabs.*

The assumption that female crabs above six inches cast only once in three years was first suggested to me when examining into the nature of “granny” crabs. This name is given by the fishermen of Port Erin to crabs occurring in the late summer and early autumn which have dirty and discoloured shells and broken claws. These crabs, if eaten, have a bitter taste and a powerful purgative effect. The fishermen believe they are diseased crabs, and always kill such when captured. There appears to be no adequate reason for believing that these crabs are diseased. The fact that they occur in considerable numbers every year during the late summer and early autumn is sufficient to render this suggestion doubtful. The general condition of these crabs leads me

\* Williamson has pointed out that if the soft mature female fails to be fertilised, it will probably cast again in the following year.

to believe that they are merely crabs ready for casting.\*

Mr. T. N. Cregeen, of the Biological Station, Port Erin, kindly examined and measured for me a number of crabs during the summer of 1907. The table inserted below gives a summary of the results obtained.

One thousand and ninety-four crabs were examined, and of this number 318 were males and the remainder females. Of the 776 females, 112 were "grannies." It will be observed that there are no male "grannies" in the list, and that practically the whole of the female "grannies" are six inches or more in width. General information from Port Erin bears this out. Male "grannies" and small female "grannies" are almost unknown.

Crabs obtained between the Calf of Man and Bradda Head, Port Erin, during the summer (July to September) of 1907.

Greatest breadth of Carapace (in inches).	Males.	Females.		Total.
		Normal.	"Granny."	
3½—4	—	2	—	2
4—4½	27	16	—	43
4½—5	63	31	—	94
5—5½	67	90	—	157
5½—6	54	153	3	210
6—6½	38	164	18	220
6½—7	23	100	36	159
7—7½	16	58	31	105
7½—8	15	30	19	64
8—8½	13	14	4	31
8½—9	1	6	1	8
9—9½	1	—	—	1
Totals.....	318	664	112	1,094

\* In "granny" crabs that I have examined there has been a well-defined cuticle beneath the hard exoskeleton. This condition is found in crabs preparing for ecdysis.

As already stated, mature crabs generally cast from August to November, and immediately before and after ecdysis their flesh is "watery" and has a bitter taste, and is, therefore, unfit for food. The above symptoms are also characteristic of the "granny" crab.

"Grannies" are found only amongst females above six inches in breadth. The explanation of this is that those females below this size do not retain their shells long enough for the latter to acquire the discoloured and broken appearance. An interval of two years between successive castings is evidently insufficient to produce this effect.

This diminution in the frequency of casting in the females above six inches may be due to the general rule that as the crab grows older the period between successive castings tends to become longer until a time is reached when ecdysis ceases altogether. But this explanation does not appear to be sufficient to account for the supposed difference between males and females in this respect. An important factor in determining the time of casting is the condition of the reproductive organs. Ecdysis will not take place in the female so long as there is a supply of spermatozoa in the spermathecae. The supply of spermatozoa received by the soft female is generally sufficient to fertilise at least two batches of eggs in successive winters, and it is highly probable that the older crabs will spawn three times between each moult. Williamson has emphasised this point, and has also stated that the soft female which, for any reason, does not become fertilised, will cast in the following summer. The frequency of ecdysis, then, in mature females is influenced by the condition of the spermathecae, and it is probable that on this account the older females will cast less frequently than the younger ones.



These conditions do not affect the male. In the female the casting time is of double importance, as it is at that period that fertilisation is effected. In the male, however, ecdysis would appear to be important only as a period of growth. It appears to me, therefore, from an examination of all the evidence obtainable, that male crabs above six inches in breadth continue to cast once in two years, and it is probable that this is the case until ecdysis stops. This rule cannot be an invariable one, as there are a few records of male crabs which have not undergone the casting process for at least three years.

My suggestion that the males above six inches cast more frequently than the females of a similar size, and, therefore, do not become "grannies," is borne out, not only by an examination of the statistics given above, but also by some figures which I quote from Williamson.\* These figures give a comparison of hard and soft mature crabs taken off Dunbar. I have only included those figures dealing with the casting period.

Date.	Hard crabs above 4½ ins.		Soft crabs above 4½ ins.	
	Males.	Females.	Males.	Females.
Aug. 4, 1899 .....	26	77	1	8
Sept. 23, 1899 .....	76	104	235	144
Oct. 27, 1899 .....	83	160	140	87
Nov. 5, 1898 .....	269	206	64	32
Nov. 17, 1899 .....	117	60	66	48
Dec. 13, 1899 .....	196	200	56	42
Dec. 20, 1897 .....	60	110	22	4
Totals.....	827	917	584	365

Total number of males ..... 1,411

„ „ females ..... 1,282

In other words, for every 100 males (hard and soft) there are 91 females (hard and soft). For every 100 soft

\* Williamson. *Eighteenth Report*, page 102, Table V.

males there are only 62 soft females. This points to the fact that the mature males cast more often than the females. It is probable that both males and females of between four and a quarter inches and six inches cast once in two years, so that it is in the older crabs that the males cast more frequently than the females. I do not attach too much importance to the above figures, as the numbers are too small to justify their use in the question of the frequency of casting. So far as they go, however, they confirm my statement that the female crabs over six inches do not cast so often as the males of a similar size. It is, therefore, probable that the "granny" crabs are not diseased, but are merely females ready for casting. They are only found amongst females of over six inches in breadth. The reason why smaller females and males of all sizes do not become "grannies" is because they cast at least once in two years.

I have been unable to find any reference to "granny" crabs in the literature\* of the subject, but Williamson says "as a rule the shell of the old female crab is much more dirty than that of the male."† He attributes this dirtiness to the fact that the female when carrying eggs lies half buried in the mud. This explanation may have some truth in it, but it does not solve the problem as to why only female crabs above six inches in breadth become discoloured.

It is evident that the various processes which are characteristic of the life-history of the edible crab are subject to considerable variation, and it is necessary that further investigations should be made before the numerous problems can be regarded as being solved.

\* With the exception of a preliminary notice by Professor Herdman in *Twenty-first Annual Report of the L.M.B.C. (Port Erin Marine Biological Station)*, p. 25.

† Williamson. *Eighteenth Report*, p. 110.

## EXPLANATION OF PLATES.

## REFERENCE LETTERS.

- a. acc.*—Anterior accessory muscle of the scaphognathite.  
*a. art.*—Antennary artery.  
*ab. 1–6.*—Abdominal somites 1 to 6.  
*abd.*—Abdomen.  
*abs.*—Lines of absorption.  
*a. ex. B.*—Tendon of the anterior extensor of basi-ischium of chela.  
*af.*—Afferent branchial sinus.  
*af. 1.*—Do. of the podobranch of the second thoracic somite.  
*af. 2.*—Do. of the arthrobranch of the second thoracic somite.  
*af. 3.*—Do. of the podobranch of the third thoracic somite.  
*af. 4.*—Do. of the anterior arthrobranch of the third thoracic somite.  
*af. 5.*—Do. of the posterior arthrobranch of the third thoracic somite.  
*af. 6.*—Do. of the anterior arthrobranch of the fourth thoracic somite.  
*af. 7.*—Do. of the posterior arthrobranch of the fourth thoracic somite.  
*af. 8.*—Do. of the pleurobranch of the fifth thoracic somite.  
*af. 9.*—Do. of the sixth thoracic somite.  
*a. f. fl.*—Anterior flexor of the flabellum of the first maxillipede.  
*a. gl.*—Antennary gland.  
*a. i. p.*—Antero-inferior pyloric ossicle.  
*a. lb.*—Antero-lateral lobe of the bladder.  
*a. mes.*—Anterior mesopyloric ossicle.  
*amp.*—Pyloric ampulla.  
*amp. C.*—Supra-ampullary ridge.  
*a<sup>1</sup>. n.*—Nerve of the first antenna; *a<sup>2</sup>. n.*—Nerve of the second antenna.  
*ant.*—Second antenna; *ant<sup>1</sup>e.*—First antenna (antennule).  
*a. oe. lb.*—Anterior oesophageal lobe of the bladder.  
*ao. lb.*—Outer portion of the antero-lateral lobe of the bladder.  
*a. ost.*—Anterior ostia of the heart.  
*a. pl.*—Anterior pleuropyloric ossicle.  
*apoph.*—Apophysis of the mandible.  
*art. 1–etc.*—Branches of the sternal artery supplying the first and following post-oral cephalothoracic appendages.  
*a. s.*—Antero-superior dilator muscles of the fore-gut.  
*a. s. a.*—Anterior supra-ampullary ossicle.  
*as. lb.*—Anterior oesophageal lobe of the bladder.  
*a. t. l.*—Lateral accessory tooth.
- B.*—Basipodite.  
*bc. 1–5.*—Branchio-cardiac veins 1 to 5.  
*B-I.*—Basi-ischipodite.  
*bl.*—Bladder.  
*b. m.*—Basement membrane.  
*br.*—Gills.  
*br. ch.*—Branchial chamber.  
*br. e.*—Branchial excretory organ.  
*br. s. 1–5.*—Branchial sinuses 1 to 5.
- C.*—Coxopodite  
*C<sup>1</sup>.*—Carpopodite.  
*caec.*—Mid-gut caecum.  
*c. al.*—Antero-lateral cardiac muscles.  
*c. ant.*—Anterior cardiac muscles.  
*card.*—Cardiac portion of the fore-gut.  
*cd. 1.*—Dorsal antero-lateral muscles of the heart.  
*cd. 2.*—Ventral antero-lateral muscles of the heart.

*cd. 3.*—Dorsal postero-lateral muscles of the heart.

*cd. 4.*—Ventral postero-lateral muscles of the heart.

*cd. 5.*—Posterior muscle of the heart.

*cd. 6.*—Lateral posterior muscle of the heart.

*cd. al.*—Antero-lateral cardiac plate.

*cd. pl.*—Postero-lateral cardiac plate.

*c. g.*—Cerebral ganglia.

*ch.*—Chela.

*ch. ep.*—Epidermis (chitogenous epithelium).

*c. i.*—Postero-inferior cardiac muscle.

*c. lat.*—Lateral cardiac muscles.

*c. m.*—Circular muscles.

*c. lob.*—Cerebral lobe of the bladder.

*cn.*—Cornea.

*c. oe.*—Constrictor muscles of the oesophagus.

*Com.*—Commissure.

*corn.*—Corneagen (cells of ommatidium).

*c. p. v.*—Cardio-pyloric valve.

*c. py.*—Cardio-pyloric muscles.

*c. t.*—Connective tissue.

*ct. gl.*—Cutaneous gland.

*cut.*—Cuticle.

*D.*—Dactylopodite.

*d. ai.*—Antero-inferior dilator muscle of the cardiac fore-gut.

*d. art.*—Descending artery.

*Der.*—Dermis.

*d. ex. C.*—Tendon of the dorsal extensor muscle of the coxopodite.

*d. f. ex.*—Dorsal flexor muscle of the exopodite.

*d. g.*—Duct of the gland.

*di. gl.*—Digestive gland.

*d. l.*—Deeper layer of the cornea.

*d. la.*—Antero-lateral dilator muscle of the cardiac fore-gut.

*d. lp.*—Postero-lateral dilator muscle of the cardiac fore-gut.

*d. sup.*—Dorsal pyloric muscle.

*d. v. m.*—Dorso-ventral muscles.

*E.*—Epistoma.

*e. a. md.*—External adductor muscle of the mandible.

*e. b. md.*—External abductor muscle of the mandible.

*e. bl.*—Epithelium of the bladder.

*e. d.*—Ejaculatory duct.

*e. es.*—Epithelium of the end-sac.

*ef.*—Efferent vessel.

*ef. 1–9.*—Efferent vessels of gills 1 to 9.

*e. lb.*—Epigastric lobe of the bladder.

*end.*—Endopodite.

*end. s.*—End sac.

*ep. 4–12.*—Endopleurites of somites 4 to 12.

*epm. 1–19.*—Epimera of somites 1–19.

*e. st. 4–12.*—Endosternites of somites 4 to 12.

*e. st. 13.*—Last thoracic arthrophragm ("sella turcica").

*e. tu.*—Epithelium of the renal tubule of the labyrinth.

*ex.*—Exopodite.

*ex. 1–6.*—Extensor muscles of the abdominal somites 1 to 6.

*ex. B.*—Tendon of the extensor muscle of the basi-ischiun.

*ex. C.*—Tendon of the extensor muscle of the coxopodite.

*ex. C<sup>1</sup>.*—Tendon of the extensor muscle of the carpopodite.

*ex. fl.* (Fig. 29).—Extensor muscle of the flabellum.



- ex. fl.* (Fig. 30).—Extensor muscle of the flagellum.  
*ex. prot.*—Extensor muscle of the protopodite.  
*ex. py.*—Exopyloric ossicle.  
*ext. D.*—Tendon of the extensor muscle of the dactylopodite.  
*ext. ex.*—Extensor muscle of the exopodite.  
*ext. P.*—Tendon of the extensor muscle of the propodite.  
*ex. tel.*—Extensor muscle of the telson.

- f. 1–6.*—Flexor muscles of the abdominal somites 1 to 6.  
*f. B.*—Tendon of the flexor muscle of the basi-ischium.  
*f. c.*—Fat cell of the digestive gland.  
*f. C.*—Tendon of the flexor muscle of the coxopodite.  
*f. C'.*—Tendon of the flexor muscle of the carpopodite.  
*f. D.*—Tendon of the flexor muscle of the dactylopodite.  
*flab.*—Flabellum (epipodite).  
*flag.*—Flagellum.  
*fl. m.*—Muscles from the top of the “gland” to the carapace.  
*f. m. 1.*—Flabellum of the first maxillipede.  
*f. m. 2.*—Flabellum of the second maxillipede.  
*f. m. 3.*—Flabellum of the third maxillipede.  
*f. m. c.*—Ferment cell of the digestive gland.  
*f. o.*—External female genital opening.  
*f. p.*—Fracture plane.  
*f. P.*—Tendon of the flexor muscle of the propodite.  
*f. prot.*—Flexor muscle of the protopodite.  
*f. tel.*—Flexor muscle of the telson.  
*f. v.*—Ferment vesicle.

- g. 1.*—First gill. Podobranch of the second thoracic somite.  
*g. 2.*—Second gill. Arthrobranch of the second thoracic somite.  
*g. 3.*—Third gill. Podobranch of the third thoracic somite.  
*g. 4.*—Fourth gill. Anterior arthrobranch of the third thoracic somite.  
*g. 5.*—Fifth gill. Posterior arthrobranch of the third thoracic somite.  
*g. 6.*—Sixth gill. Anterior arthrobranch of the fourth thoracic somite.  
*g. 7.*—Seventh gill. Posterior arthrobranch of fourth thoracic somite.  
*g. 8.*—Eighth gill. Pleurobranch of the fifth thoracic somite.  
*g. 9.*—Ninth gill. Pleurobranch of the sixth thoracic somite.  
*g. a.*—Anterior gastric muscle.  
*g. f.*—Fat globules.  
*g. lb.*—Paragastric lobe of the bladder.  
*g. p. e.*—External posterior gastric muscle.  
*g. p. i.*—Internal posterior gastric muscle.

- h.*—Seta of the endopodite of the pleopod of the female.  
*h. art.*—Hepatic artery.  
*h. g.*—Hind gut.  
*h. l.*—Hepatic lobe of the bladder.

# *I.*—Ischiopodite.

- ia. art.*—Inferior abdominal artery.  
*i. a. f.*—Inter ampullary fold.  
*i. a. md.*—Internal adductor muscle of the mandible.  
*i. b. md.*—Internal abductor muscle of the mandible.  
*i. b. s.*—Inter-branchial septum.  
*i. caec.*—Hind-gut caecum.  
*i. e. m.*—Inner flexor muscle of the first maxilla.  
*i. ex.*—Inner flexor muscle of the scaphognathite (*i. ex. s.*, Figs. 27, 31).  
*i. f.*—Inner extensor muscle of scaphognathite.  
*i. f. m.*—Inner extensor muscle of first maxilla.

- i. gl.*—Glands of the hind-gut.
- i. l.*—Infero-lateral cardiac tooth.
- i. m. ex.*—Inner median flexor muscle of the scaphognathite.
- i. m. f.*—Inner median extensor muscle of the scaphognathite. †
- i. py. e.*—External inferior dilator muscle of the pyloric fore-gut.
- i. py. i.*—Internal inferior dilator muscle of the pyloric fore-gut.
- i. s.*—Infra-branchial sinus.

*j. d.*—Junction between the descending artery and the sternal artery.

*l.*—Gill lamella.

*lab.*—Labrum.

*lat. t.*—Lateral teeth.

*l. ex. prot.*—Lateral extensor muscle of the protopodite.

*l. f. prot.*—Lateral flexor muscle of the protopodite.

*l. g. n.*—Lateral gastric nerve.

*lig.*—Ligament.

*l. m.*—Longitudinal muscle.

*l. py.*—Lateral pyloric ossicle.

*l. s.*—Lamella blood sinus.

*M.*—Meropodite.

*m. a<sup>1</sup>.*—Muscle chamber of first antenna. †

*m. a<sup>2</sup>.*—Muscle chamber of second antenna.

*mand.*—Mandible.

*m. c.*—Mesocardiac ossicle.

*md. palp.*—Mandibular palp.

*med. p.*—Median plate of endophragmal system.

*met.*—Metastoma.

*m. ex. C'.*—Extensor muscle of the carpopodite.

*m. ex. M.*—Extensor muscle of the meropodite.

*m. ext. D.*—Extensor muscle of the dactylopodite.

*m. ext. P.*—Extensor muscle of the propodite.

*m. f. C'.*—Flexor muscle of the carpopodite.

*m. f. D.*—Flexor muscle of the dactylopodite.

*m. f. M.*—Flexor muscle of the meropodite.

*m. f. P.*—Flexor muscle of the propodite.

*m. j.*—Mid-gut.

*m. o.*—Male genital opening.

*m. py.*—Middle pyloric ossicle.

*m. s. a.*—Middle supra-ampullary ossicle.

*M. V.*—Main vesicle.

*mx<sup>1</sup>.*—First maxillipede.

*mx<sup>2</sup>.*—Second maxillipede.

*mx<sup>3</sup>.*—Third maxillipede.

*n.*—Nucleus.

*n. 1.*—*n. 9.*—Nerves arising from the ventral nerve mass of the thorax.

*n. ab.*—Abdominal nerve.

*n. c.*—Nerve commissure.

*n. f.*—Foramer of ventral nerve mass for descending artery.

*n. i.*—Nerve to hind-gut.

*n. l.*—Nerve to digestive gland.

*n. m.*—Nerve to the mandibular muscles.

*n. po.*—Transverse post-oesophageal connective.

*n. t.*—Nerve to the integument.

*o.*—Eye.

*o. art.*—Ophthalmic artery.

*oe.*—Oesophagus.

- oe. ai.*—Antero-inferior dilator muscle of the oesophagus.
- oe. as.*—Antero-superior dilator muscle of the oesophagus.
- oe. l.*—Lateral dilator muscle of the oesophagus.
- o. e. m.*—Outer flexor muscle of the first maxilla.
- oe. p.*—Posterior dilator muscle of the oesophagus.
- o. ex.*—Outer flexor muscle of the scaphognathite (*o.ex.s.*, Figs. 27, 31).
- o. f.*—Outer extensor muscle of the scaphognathite.
- o. f. m.*—Outer extensor muscle of the first maxilla.
- o. g.*—Optic ganglion.
- o. l. s.*—Outer lamellar sinus.
- o. m. c.*—Ophthalmic muscle chamber.
- o. m. ex.*—Outer median flexor muscle of the scaphognathite.
- o. m. f.*—Outer median extensor muscle of the scaphognathite.
- om. n.*—Oculo-motor nerve.
- o. n.*—Optic nerve.
- o. n. fib.*—Optic nerve fibres.
- op.*—Operculum of excretory opening.
- op*<sup>1</sup>.—Inner side of operculum.
- op. b. s.*—Ophthalmic blood sinus.
- o. ped.*—Optic peduncle.
- o. py.*—Pyloric ossicle.
- orb.*—Orbit.
- ov.*—Ovary.
- ov. art.*—Ovarian artery.
- ovd.*—Oviduct.

*P.*—Propodite.

- P. 1-4.*—Walking legs 1 to 4.
- p. 1-2.*—1st and 2nd abdominal appendages of male.
- p. acc.*—Posterior accessory muscle of the scaphognathite.
- p. c. p.*—Pro-cephalic processes.
- pec.*—Pectineal ossicle.
- ped.*—Eye peduncle.
- Per.*—Pericardium.
- per. gl.*—"Pericardial pouch."
- p. ex. B.*—Tendon of the posterior extensor muscle of the basi-ischium.
- p. f. B.*—Tendon of the posterior flexor muscle of the basi-ischium.
- p. g.*—Paroesophageal ganglion.
- pg. c.*—Pigment cell.
- pg. i.*—Inner pigmented layer of the eye.
- p. g. n.*—Posterior gastric nerve.
- pg. o.*—Outer pigmented layer of the eye.
- pig. l.*—Pigment layer.
- pl. art.*—Postero-lateral artery.
- p. lb.*—Progastric lobe of the bladder.
- p. mes.*—Posterior mesopyloric ossicle.
- p. n.*—Postero-lateral nerve.
- pod. br.*—Podobranch.
- p. o. lb.*—Post-oesophageal lobe of the bladder.
- p. ost.*—Posterior ostia of the heart.
- pp.*—Pleuropyloric wall.
- p. pec.*—Prepectineal ossicle.
- prot.*—Protopodite.
- pr. p.*—Propyloric ossicle.
- p. s. a.*—Posterior supra-ampullary ossicle.
- pt. c.*—Pterocardiac ossicle.
- pt. pec.*—Post-pectineal ossicle.
- pyl.*—Pyloric region of the fore-gut.
- py. lat.*—Lateral pyloric muscles.

*r. br.*—Roof of the pre-branchial chamber.

*ret.*—Cells of the retinula.

*rhab.*—Rhabdome.

*rost.*—Rostrum.

*S*<sup>1</sup>. — *S*<sup>19</sup>. — Sterna of somites 1 to 19.

*s. a*<sup>1</sup>. — Socket of first antenna.

*s. a*<sup>2</sup>. — Socket of second antenna.

*sa. art.*—Superior abdominal artery.

*s. amp.*—Supra-ampullary wall of the pyloric region of the fore-gut.

*sal. g.*—Salivary (oesophageal) glands.

*s. art.*—Sternal artery.

*sb.*—Striated border of the cell.

*scaph.*—Scaphognathite.

*s. ch.*—Blood sinus from the chela.

*s. dt.*—Subdentary ossicle.

*s. h.*, *s. hr.*—Sub-hepatic region of carapace.

*s. l.*—Supraciliary lobe.

*s. lb.*—Supra-hepatic lobe of the bladder.

*s. mx. 2.*—Blood sinus from the second maxillipede.

*s. mx. 3.*—Blood sinus from the third maxillipede.

*s. Pi.*—*s. P. 4.*—Blood sinus from the walking legs 1 to 4.

*sp. a.*—Frontal spine.

*sp. d.*—Dorsal spine.

*sp. l.*—Lateral spine.

*spt.*—Spermatheca.

*st.*—Stalk of the egg attached to the seta of the endopodite.

*st. g.*—Stomatogastric ganglion.

*st. i.*—Inferior root of the stomatogastric nerve.

*st. n.*—Stomatogastric nerve.

*st. s.*—Superior root of the stomatogastric nerve.

*t. c. ex.*—Tendon of the extensor muscle of the exopodite.

*tel.*—Telson.

*test.*—Testis.

*t. ex. ab.*—Tendon of the external abductor muscle of the mandible.

*t. ex. ad.*—Tendon of the external adductor muscle of the mandible.

*t. ex. M.*—Tendon of the extensor muscle of the meropodite.

*t. f. ex.*—Tendon of the flexor muscle of the exopodite.

*t. g.*, *t. gm.*—Ventral thoracic nerve mass.

*t. int. ad.*—Tendon of the internal adductor muscle of the mandible.

*t. n.*—Tegumentary nerve.

*tu.*—Renal tubule of the labyrinth.

*u. c.*—Urocardiac ossicle.

*up. f.*—Uropyloric fold.

*u. py.*—Uropyloric ossicle.

*v.*—Globules in the epithelial cells of the mid-gut.

*val.*—Pyloric valves.

*v. d.*—Vas deferens.

*v. ex. C.*—Tendon of the ventral extensor muscle of the coxopodite.

*v. f. ex.*—Ventral flexor muscle of the exopodite.

*vit.*—Vitrella (cells of the ommatidium).

*v. m.*—Egg membranes.

*v. oe. g.*—Ventral oesophageal cutaneous glands.

*y. c.*—Young cells of the tubules of the digestive gland.

*y. gr.*—Yolk granules.

*z. c.*—Zygocardiac ossicle.



## PLATE I.

- Fig. 1. *Cancer pagurus*, from above. Small specimen.  
Fig. 2. *C. pagurus*, female, from below. Only the stumps of the pereopods are shown. This figure shows the shape of the abdomen, and also the "pleural groove."  $\times \frac{1}{2}$ .  
Fig. 3. *C. pagurus*, male, from below. Only the stumps of the pereopods are shown.  $\times \frac{1}{2}$ .

## PLATE II.

- Fig. 4. First antenna (antennule) of right side, seen from below.  $\times 2$ .  
Fig. 5. Right second antenna, from below.  $\times 2$ .  
Fig. 6. Right mandible, from below. The apophysis is also shown with the tendons of the external adductor, the internal adductor and the external abductor muscles.  $\times 1$ .  
Fig. 7. Right first maxilla, from below.  $\times 1$ .  
Fig. 8. Right second maxilla and scaphognathite, from below.  $\times 1$ .  
Fig. 9. Right first maxillipede, from below.  $\times 1$ .  
Fig. 10. Right second maxillipede, with podobranch, from below.  $\times 1$ .  
Fig. 11. Right third maxillipede, with podobranch, from below.  $\times 1$ .  
Fig. 12. Anterior view of the right chela (first pereopod).  $\times 1$ .  
Fig. 13. Anterior view of the right third walking leg (fourth pereopod).  $\times 1$ .  
Fig. 14. First abdominal appendage of male of right side.  $\times 1$ .  
Fig. 15. Second abdominal appendage of male of right side.  $\times 1$ .  
Fig. 16. First and second abdominal appendage of male, viewed from left side.  $\times 1$ .  
Fig. 17. Anterior view of a right abdominal appendage of female.  $\times 1$ .

## PLATE III.

- Fig. 18. The endophragmal system viewed from above. On the right side the thoracic epimera have been removed in order to display the endopleurites. The following parts have also been removed:—The carapace, with the exception of the anterior portion of the sub-hepatic region; the membranous roof of the branchial chamber; the abdomen; the cephalothoracic appendages (with the exception of the mandibles); the gills; and all the soft parts of the body.  $\times 1$ .
- Fig. 19. The sternum of the pre-oral cephalic region, viewed from above. The dorsal part of the carapace has been removed, as well as the pre-oral cephalic appendages and the soft parts.  $\times 2$ .
- Fig. 20. The sternum of the pre-oral cephalic region, from below. The first and second antennae of the left side have been removed to display their sockets and muscle chambers. The long peduncle of the left eye is shown, and also the labrum.  $\times 2$ .
- Fig. 21. Anterior and ventral view of the right chela. The anterior wall of each segment has been cut out, and the soft parts removed in order to display the tendons.  $\times \frac{2}{3}$ .
- Fig. 22. Posterior view of the basal portion of the second walking leg (right side). The posterior wall of the coxopodite has been removed in order to display the tendons of that segment and also of the basi-ischium.  $\times 1$ .
- Fig. 23. Posterior view of the base of the last walking leg of the right side. The posterior wall of the coxopodite has been removed in order to display the tendons of the coxopodite and of the basi-ischium.  $\times 1$ .

## PLATE IV.

- Fig. 24. Vertical section through the integument of a soft crab.  $\times 550$ .

- Fig. 25. Right abdominal appendage of female, viewed from behind. To show the muscles of the protopodite and exopodite, the posterior walls of the protopodite, exopodite and endopodite have been removed.  $\times 3$ .
- Fig. 26. Anterior view of the right first maxilla, in order to show the muscles.  $\times 2$ .
- Fig. 27. Anterior view of the right second maxilla, to show the extensor muscles of the scaphognathite.  $\times 1\frac{1}{2}$ .
- Fig. 28. Anterior view of the right second maxilla, in order to show the muscles of the scaphognathite. The extensor muscles have been cut short, and the basal and inner portions of the scaphognathite have been opened in order to show the flexors and accessory muscles.  $\times 1\frac{1}{2}$ . (To see this appendage in its natural position, the figure must be rotated to the left through an angle of  $45^\circ$ .)
- Fig. 29. Posterior view of part of the first maxillipede of the right side, in order to show the muscles of the maxillipede and flabellum. The posterior flexor and the extensor muscles of the flabellum are cut through.  $\times 2$ .
- Fig. 30. Posterior view of the third maxillipede of the left side. The ventral walls of the various parts have been removed in order to display the muscles.  $\times 1\frac{1}{2}$ . (The base of the appendage is to the left of the figure.)
- Fig. 31. A dissection of the anterior part of the cephalothorax to display the muscles of that region. The dorsal portion of the carapace has been removed, and also the soft parts, with the exception of the muscles.  $\times 2$ .
- Fig. 32. Dissection of the female abdomen from the ventral side to display the extensor muscles. The ventral wall and appendages have been removed, as well as all the soft parts.  $\times \frac{1}{2}$ .
- Fig. 33. Semi - diagrammatic longitudinal section through the abdomen of the female, to show the extensor and flexor muscles.  $\times \frac{1}{2}$ .

PLATE V.

- Fig. 34. A dissection from above to display the various parts of the alimentary canal. The dorsal part of the body has been removed, as well as the gonads. The gills are not shown. The digestive gland is only shown on the left side.
- Fig. 35. Vertical transverse section through the oesophagus, to show especially the oesophageal glands.  $\times 35$ .
- Fig. 36. Transverse section through the pyloric region of the fore-gut.  $\times 30$ .
- Fig. 37. Transverse section through a tubule of the digestive gland.  $\times 120$ .
- Fig. 38. A "fat cell" of the digestive gland.  $\times 430$ .
- Fig. 39. A "ferment cell" of digestive gland.  $\times 430$ .

PLATE VI.

- Fig. 40. The fore-gut from the left side, showing the ossicles.  $\times 1\frac{1}{2}$ .
- Fig. 41. The pyloric region of fore-gut, dorsal view.  $\times 3$ .
- Fig. 41a. Anterior view of the pro-pyloric ossicle.  $\times 4$ .
- Fig. 42. Transverse section through the region of the green gland, to show the parts of the bladder. Only one side shown.  $\times 8$ .
- Fig. 43. The ossicles of gastric mill, from above.  $\times 2$ .
- Fig. 44. The ossicles of the gastric mill, from below. The fore-gut has been opened ventrally. The left zygocardiac ossicle has been rotated in order to show the lateral teeth.  $\times 3$ .

PLATE VII.

- Fig. 45. The fore-gut from the left side, showing the intrinsic and extrinsic muscles.  $\times 3$ .
- Fig. 46. Anterior view of the fore-gut, to show the muscles.  $\times 1\frac{1}{2}$ .
- Fig. 47. The fore-gut from above, showing the intrinsic and extrinsic muscles.  $\times 1\frac{1}{2}$ .



- Fig. 48. The fore-gut from behind, showing the intrinsic and extrinsic muscles. The postero-lateral dilator has been cut near its insertion at the right side in order to show the antero-lateral dilator muscle. The right posterior dilator of the oesophagus has also been cut in order to expose the lateral dilators of oesophagus.  $\times 3$ .
- Fig. 49. Dorsal view of the heart.  $\times 2$ .
- Fig. 50. View of the heart from the left side.  $\times 2$ .

## PLATE VIII.

- Fig. 51. General view of the blood system from above. The dorsal region of the carapace has been removed. On the right side the organs remain intact, but on the left side the ovary and digestive gland have been removed. One gill on the left side has also been turned outward in order to show the afferent branchial vein and the branchio-cardiac vein. In this region, also, the flabella of the second and third maxillipedes are seen lying beneath the gills. The course of the bladder is shown on the left side.  $\times 1$ .

## PLATE IX.

- Fig. 52. View of ventral region of post-oral cephalothorax to show the sternal artery and its branches. All the muscles have been removed. On the right side the arteries going to the legs are cut short. The inferior abdominal artery is also cut short.  $\times \frac{1}{2}$ .
- Fig. 53. Dissection of abdomen from the dorsal side to show the superior abdominal artery. The tergal region of the abdomen has been removed.  $\times 1$ .
- Fig. 54. Dissection of the posterior region of the thorax to show the pericardium, heart, branchio-cardiac veins and efferent branchial veins. Only seven of the gills are shown on the left side, and on the right side only the roots of the

nine gills are shown. On the right side the epimeral wall has been removed in order to show the course of the branchio-cardiac veins, and also to show the connection between the latter and the pericardium.  $\times 1$ .

- Fig. 55. A dissection of the epimeral region of the thorax from the right side, in order to show the positions of the branchial sinuses, the infra-branchial sinus, the afferent branchial sinuses, and also the sinuses coming from the thoracic legs.  $\times 1$ .
- Fig. 56. Diagrammatic section through the thorax in the region of the heart, to show the blood system and the general arrangement of the organs. The tendons of the first walking legs are shown.  $\times \frac{1}{2}$ .

#### PLATE X.

- Fig. 57. Dissection of the left side to show the extensions of the bladder. The dorsal region of the carapace has been removed. The fore-gut has been cut through at the oesophagus and removed. The gonads and the digestive gland have also been taken away. The antennary gland is represented by a dotted circle.  $\times 1$ .
- Fig. 58. Semi-diagrammatic sagittal (vertical longitudinal) section of the antennary gland. The anterior part of the gland is to the right.  $\times 60$ .
- Fig. 59. Detailed drawing of part of previous figure, showing the epithelial cells of the bladder, end sac and the renal tubule.  $\times 90$ .
- Fig. 60. Section through the mass of cutaneous glands opening on to the epistoma.  $\times 210$ .
- Fig. 61. Section showing the epithelial cells of the mid-gut, with characteristic striated border.  $\times 550$ .
- Fig. 62. Longitudinal section through part of the wall of the hind-gut, about the middle of the abdomen, showing cutaneous glands.  $\times 165$ .

Fig. 63. Dorsal view of the gills of the left side in their natural position, lying upon the thoracic epimera. The roofs of the branchial and prebranchial chambers have been removed. The scaphognathite has been turned over to the inner side, in order to show the maxillipedes. The flabellum of the first maxillipede is shown lying upon the gills (the longitudinal axis of the body is at an angle of  $60^{\circ}$  with the long axis of this plate).  $\times 1$ .

Fig. 64. View of the branchial chamber of the left side. Each gill has been removed at its base, so that only the points of attachment of the gills are shown. The scaphognathite and first maxillipede (with flabellum) have been removed. By removing the gills the flabella of the second and third maxillipedes are exposed.  $\times 1$ .

#### PLATE XI.

Fig. 65. Diagrammatic transverse section across a gill, showing the branchial septum, the afferent and efferent vessels and the lamellae.  $\times 3$ .

Fig. 66. Longitudinal section through a gill in the region of the afferent vessel.  $\times 100$ .

Fig. 67. Transverse section through a gill, to show especially the branchial excretory cells in the septum.  $\times 24$ .

Fig. 68. A dissection of the nervous system from above. The alimentary canal has been cut through the region of the oesophagus and removed, but the stomatogastric system is shown. The nerves arising from the left side of the cerebral ganglia are alone shown. Those of the right side have been cut, only the nerves arising from the right side of the thoracic ventral mass are shown. The abdominal nerve is only shown as far as the anterior region of the abdomen.  $\times 1$ .

- Fig. 69. Longitudinal section through the eye. The optic ganglion is also shown.  $\times 12$ .
- Fig. 70. Enlarged drawing of two of the ommatidia from the previous figure.  $\times 450$ .
- Fig. 71. Transverse section across one of the ommatidia in the previous figure, through the rhabdome and retinulae.  $\times 1000$ .
- Fig. 72. Transverse section across one of the ommatidia in the previous figure, through the vitrella and the pigment cells.  $\times 1000$ .
- Fig. 73. Surface view of the cornea, showing one of the corneal facets.  $\times 750$ .
- Fig. 74. Olfactory seta taken from the exopodite of the first antenna.  $\times 1100$ .
- Fig. 75. Auditory seta ("hooked seta") from the auditory sac of the first antenna.  $\times 400$ .
- Fig. 76. Auditory seta ("group seta") from the auditory sac of the first antenna.  $\times 300$ .

## PLATE XII.

- Fig. 77. Reproductive system of a fairly mature female, showing the double ovary, the spermathecae and the oviducts.  $\times 1$ .
- Fig. 78. Reproductive system of an immature male, showing the paired testes, the vas deferens and the ejaculatory duct. The fore-gut is also shown in position.  $\times 2$ .
- Fig. 79. Section through an almost ripe ovary, showing the eggs filled with yolk granules. The details are only inserted in one egg.  $\times 190$ .
- Fig. 80. A very early stage in the development of the embryo, attached to a seta of an endopodite of a female pleopod. This drawing shows the method of attachment.  $\times 50$ .
- Fig. 81. Ripe spermatozoon, showing the two processes. Taken from spermatheca of female.  $\times 1400$ .
- Fig. 82. Some of the epithelial cells of the bladder of the excretory system. The striated nature of the protoplasm is shown.  $\times 650$ .



## PLATE XIII.

- Fig. 83. Protozoëa of *Cancer pagurus*, two hours after hatching. View from the left side.  $\times 120$ .
- Fig. 84. Telson of the same stage, from above.  $\times 175$ .
- Fig. 85. Zoëa of *Cancer pagurus*, thirty hours after hatching, showing the maximum development of the frontal and dorsal spines.  $\times 90$ .
- Fig. 86. Dorsal view of the cephalothorax of the same stage. The dorsal and frontal spines are cut off short.  $\times 110$ .
- Fig. 87. Telson of the same stage, from above.  $\times 160$ .

## METHODS OF PLANKTON RESEARCH.

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## INTRODUCTION.

During the last few years there has been a great development in the study of those organisms which are found floating in the waters of seas and lakes, and which, though having in many cases the power of swimming, are practically as much at the mercy of the winds and currents as inanimate floating objects. Such organisms are denoted by the term "Plankton," and, as their full importance in the metabolism of the ocean has become appreciated, so has this branch of zoology and botany, which may be termed Planktonology, advanced from qualitative to quantitative investigation. The work has been carried on by both botanists and zoologists, but owes its growth mainly to the latter, and in great part to the German School, from the time of Johannes Müller onwards to the present quantitative scientific study of the Plankton which originated through the outstanding and fundamental work of Victor Hensen, Professor of Physiology in the University of Kiel. Hensen's work (1) appeared in 1887, but as far back as 1867 he was interested in the investigation of the sea in the interests of Fishery questions, and held the view that an attempt to estimate the productiveness of the sea would be an important step, both scientifically and economically. Finally, whilst working at the question of coast fisheries he attempted to determine the number of fish in a defined region by counting and estimating the number of floating fish eggs. This led to the idea that it was both possible and necessary

to investigate quantitatively the planktonic fauna and flora, the source of food for the larger sea animals.

With these facts in view, Hensen invented the nets and methods by which the German investigators have, since that time, diligently worked. These methods were described by Dr. J. T. Jenkins in the *Trans. Liverp. Biol. Soc.* for 1901, and the purpose of the present paper is to bring the description of the German Plankton methods up to date and to briefly discuss some results of the work. I have been in a fortunate position in this respect, that I have been able, myself, to handle the apparatus whilst participating in the actual expeditions in the North Sea and Baltic. I must thank Professor Brandt for his kindness in securing permission for me to travel on the German Investigation Steamer "Poseidon," and Professors Lohmann and Apstein for their ever willing help and explanations.

Essentially from first to last, Hensen and his co-workers have had one aim in view—the better determination of the "see-saw" of life in the water and the laws governing this. It devolved, therefore, into a determination of what plankton was to be found in the sea at a given time and place, and how this mass changed with the change of time or of place, or of both, in quantity and quality. How far this aim has been realised will be discussed after an account of the nets and apparatus used.\*

### THE PLANKTON NETS.

As described by Jenkins, the quantitative net was the apparatus which Hensen invented as the most satisfactory means by which the organisms in a known

\*The blocks for figs. 1, 3, 4 and 7 have been kindly lent by the *Commiss. f. wissensch. Meeresuntersuchung*. The apparatus described in this paper for the quantitative work is manufactured by Zwickert, Optician, Kiel.

quantity of water could be estimated. These quantitative nets are lowered perpendicularly in the water to a certain depth and then raised to the surface, so that any towing in a horizontal direction is avoided. Thus a vertical column of water passes through the net, and the volume of this has to be calculated before the net is used for quantitative work, since it is obvious that not the same quantity of water passes through the net as would pass through the open mouth if no net was attached to it. In short, the problem has been to devise an apparatus which should be handy and workable from a small ship, which would take up a definite quantity of water from the sea, and abstract as thoroughly as possible the organisms contained therein.

Silk nets still form the apparatus most used for this purpose, but as Lohmann (**11**, **13** and **18**) has shown, the results are only accurate to a certain point and must be supplemented by other methods, according to the aim of the research. The large Hensen vertical net was described in Dr. Jenkins' paper, and therefore need not be mentioned further. Apstein has shown that a much smaller net can be conveniently used with much saving of time and labour, and under conditions where the larger net is impossible, in the absence of a steamer.

At the present time the net used in the German investigations above all others, and thus the chief implement for plankton research, is the Middle Plankton Net of Apstein (**7**). The large Hensen net is used only for special purposes, one of which is the quantitative estimation of fish eggs, where a large catch of plankton is desirable, or for other large organisms that do not occur frequently enough for accurate measurements to be made with the smaller nets. In form the Apstein net is almost the same as the Hensen. It is shown in fig. 1 to consist



of three parts:—(1) The filtering net itself; (2) the metal filtering bucket; and (3) the conical mouth piece. The mouth piece is constructed of thick material, which does not allow water to filter through it. It is supported by two brass rings, one of which serves to keep the mouth of the net open, and to this ring are attached the cords, three in number, which support the net. This upper ring, and therefore the mouth of the net, has a diameter of 14 centimetres. The lower brass ring is thicker and is supported by the mouth-piece cloth itself and by three cords which are attached to the upper ring and take the place of the three iron rods that separate the two rings in the Hensen net.



Fig. 1.—Apstein's middle and small plankton nets.

The length of the mouth-piece is 20 cm. down the side. This part of the net serves three purposes:—  
 (1) It prevents mud passing into the net if it be lowered on to very soft ground; (2) it prevents the catch from being upset in a rough sea; (3) it performs the function of keeping the net mouth small in comparison with the filtering area of the net.

It is obvious that the water will be most completely filtered if as little as possible is allowed to enter and the greatest facility is given for it to leave the net. If the mouth-piece was not present, a greater quantity of water would attempt to stream through the large ring than could be filtered by the area of the net, and, therefore, as the net was hauled up, water would remain in the entrance and the water of the vertical

column would be simply pushed aside without passing through the net. Thus a reliable sample would not be obtained.

The Net, which is the actual filtering agency, must be made of some material that will stand the work well—filter the organisms as thoroughly as possible, and most important of all, be so manufactured that the size and shape of the meshes will not easily alter, so that the formula calculated for determining the filtration coefficient for the net may remain always applicable. The best material has been proved to be “Müllergaze” or “bolting silk,” and the grade used for quantitative nets is denoted by the number 20. For this particular tissue the filtration capacity has been calculated. The net must be carefully made, because in order to determine the quantity of water from which the plankton has been abstracted, an extremely complicated mathematical and practical research is necessary, and this when once made for a particular silk and shape of net should be applicable to all others of the same size, shape and material. Furthermore, in order to compare the results of workers in different countries, it is of course advisable that a standard net such as the Middle Plankton Net should be used everywhere.

The silk net is attached above to a strip of strong linen cloth or canvas about an inch wide, which is fastened to the lower brass ring of the conical mouth-piece. It is conical in shape with a truncated end, which forms the bottom of the net and is fastened to a metal bucket by means of a clamp ring consisting of a strip of thin brass, which is bent into a ring with the two ends bearing projections perforated by holes so that they can be screwed together.

The brass bucket (fig. 1), being of considerable

weight, is not allowed to hang on the silk net, but is supported separately by three cords, which are fastened to the stout lower ring of the conical mouth-piece.

The size of the net and the method of cutting it can be seen from fig. 2, where the right-hand sketch is a representation of the net when sewn up, and the other figure is the same unrolled, showing the pattern as it should be cut out. For the middle plankton net the radius  $R$  of the mouth of the net is 20 cm. The radius  $r$

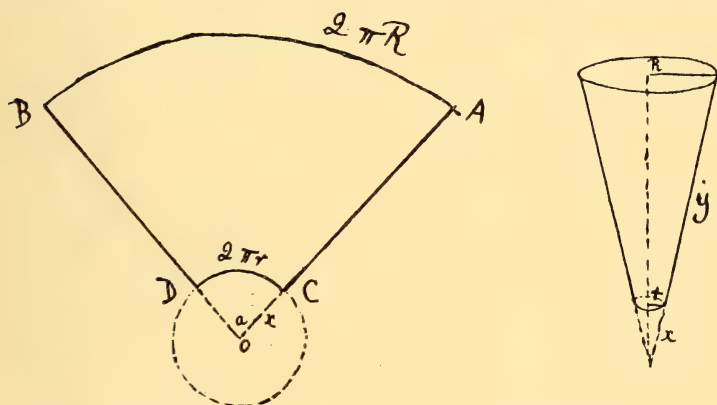


FIG. 2.— $R = 20$  cm.;  $r = 3$  cm.;  $x = 17.65$  cm.;  $y = 100$  cm.; and the angle  $a = 61.2^\circ$ .

of the bottom of the net, where it is attached to the metal bucket, is 3 cm. The portion of the cone is cut off (fig. 2,  $x$ ) is 17.65 cm., and the length of side remaining 100 cm. Care must be taken to allow of a margin when cutting out the pattern, so that the edges AC and BD can overlap and be sewn together, the upper edge of the net be sewn to the linen strip, and the bottom of the net fixed by the clamp ring to the bucket.

The metal bucket serves as a receiver for the plankton and furthermore does away with the use of the filtrator invented for use with the great Hensen

net. It can be described therefore as the filtering bucket. It consists of a 14 cm. long brass cylinder, whose sides are cut out, with the exception of three narrow pieces, so that there remains 3 cm. of cylinder above and 4 cm. below. A piece of No. 20 silk is then placed outside the three brass pieces and fixed above and below to the cylinder by the clamp rings. In addition, three brass plates are screwed against the pieces so that the silk filtering tissue lies between them and is quite taut over the three windows of the bucket. The upper part of the cylinder is supplied with a screw thread so that it can be screwed on to the brass ring, to which the net is attached. From the middle of the floor of the cylinder a tube descends, which is provided with a tap.

This completes the description of the ordinary Apstein net, but in order to make comparisons of the various layers, and the plankton at different depths (a most important factor, for it will be shown that the plankton differs both quantitatively and qualitatively considerably according to the depth and probably as a result of changes in the light conditions, salt contents or temperature), it is necessary to have a method by which the net can be hauled through a certain distance and then closed. In fact, when working with the vertical net, the column from the bottom to the surface should be divided into regions, and the temperature, and salt contents, together with the plankton, determined for each region separately. Various arrangements have been invented for closing the net. The following is about the most satisfactory now in use (fig. 3). The net differs from the one just described only in the possession of closing apparatus. The upper brass ring of the conical mouth-piece is replaced here by a much broader and heavier brass ring. Across the middle of this runs a stout bar, and directly



above this two semi-circular brass lids are hinged so that they can fall down, one on each side, and lying over the brass ring completely close the opening. In order to make the closure more water-tight, the net ring bears a rubber ring on its upper surface, and there is further a piece of stout waterproof canvas fixed by screws over the



Fig. 3.—Closing apparatus at mouth of net.

hinge itself, so that no water can pass through the crevices into the net when it is being hauled up to the surface. One of these trap-doors (both together resemble a "butterfly valve") is perforated to allow air to enter the net when it is raised out of the water. This is necessary because when lifting the hermetically sealed net out of the water, the water contained in it filters out through the silk, and unless air is allowed to enter the filtration is hindered, and, moreover, the whole net collapses. In order that no water shall pass in through the opening for the air, it is provided with a balanced valve, so that

it remains closed as long as the net is being pulled through the water, and opens immediately it is above the surface. The essential apparatus for closing the net at any particular moment is shown in the photograph (fig. 3). The apparatus in the photograph differs slightly from that

here described, but only in one detail, viz., two ropes with knots are present in place of the two wires. It will be seen that the net can be supported in two ways—(a) by the lids; (b) by the three cords attached to the upper brass ring of the net. The first is the condition when the net is descending and whilst it is being pulled up through the region which is to be fished. The second is the condition when the net has been closed by a heavy weight run down the rope, which falls upon the closing apparatus and releases the two lids. In this condition it can be hauled up to the surface without any water entering. I have seen this closing apparatus used down to depths of 200 fathoms, and it has worked satisfactorily, though it should always be watched in case anything catches and the lids do not close at the proper time.

It will be seen that the net when lowered is open. This is the case for the ordinary net also, but since the water only enters the net through the filtering tissue, the various organisms will remain outside. It is only when the water enters the net through the mouth that it will make any catch.

#### METHOD OF USING THE QUANTITATIVE NET.

The wire or rope supporting the net should not run directly from the winch over fixed pulleys to the net, but should pass over a pulley which is supported by an “accumulator.” This is particularly important when using the large net in a rough sea, or when the boat is rolling considerably, since, otherwise, the sudden pull as the side of the boat rises to a wave is liable to damage the net, besides rendering the results inexact, owing to the pressure constantly varying. It is essential that the net should be pulled up with an equal speed, and therefore pressure, and the accumulator aids this considerably.

When the boat is rolling very much, a clever winch man can so work as to wind the net up only as the ship's side descends, while the ascent serves to haul up the net. For systematic plankton work of this kind a steam winch is very desirable. On the German Investigation Steamer "Poseidon" there is a very complete set of winches, and the rope used for the net is of thin wire. This wire passes over a very essential, though small, piece of apparatus fixed to the deck, and consisting of a wheel about one foot in diameter, so geared that it records every metre of rope that passes over it, and therefore the exact depth of the net can be seen by simply looking at the figures on the meter face.

Furthermore, the gradual changing of the figures, as metre after metre passes out or in, can be easily timed, and from this the speed at which the net is being hauled in can be adjusted. In order to determine the volume of water filtered by the net, a formula has been calculated, depending on the size and shape of the net, the filtration capacity of the silk, and the speed at which the net is hauled through the water. The net must be hauled up at a speed of half a metre per second in order that the coefficient determined for this type of net can be used. One has then only to multiply the number of organisms found in the catch or the volume of the catch by 80 to give the number or volume present in a column of water of the length the net has been hauled through and of area equal to one square metre.

In any case, in quantitative work, where the results of different catches are to be compared, and whether the number of organisms in a particular quantity of water is needed or not, it is necessary that the net should always be hauled up at the same speed, otherwise the pressure in the net will not be the same and a greater or less quantity

of water will be filtered, and different volumes of catch will be obtained. Thus, if the quantity and constitution of the plankton were exactly alike at two stations, but the net was hauled up with a greater speed at one than at the other, the volume, and moreover the constitution, of the two catches would be different, even though the distance through which the net was hauled was the same at both places. Hence the necessity of some recording machine.

It is further important, in quantitative work, that the net should descend and ascend vertically. If this is not the case, two errors may enter into the work:—(1) The net will be towed more or less in a horizontal direction and not give a true picture of the plankton in a column of water. (2) The depth recorded by the amount of rope paid out will not give the true depth of the net.

In order to obviate this oblique descent, which occurs when there is any considerable current in the water, the net should be weighted with a heavy leaden weight slung under the filtering bucket. The net provided with the closing apparatus does not need such a heavy weight as the ordinary Apstein open net, since it is naturally somewhat heavy. Both, however, should be weighted, otherwise even in a region with no current their descent would be too slow. It is always safer to sink the nets as rapidly as possible, particularly if there be much current.

Herdman (17) refers to the "Nansen" net and its easy method of working, due in part to its lightness. If, however, the Nansen net is to be used as a satisfactory vertical net, it must be weighted until it is relatively as heavy as the other plankton nets. Furthermore, it may be slightly inaccurate for quantitative work, since it lacks the conical mouth-piece, and, in addition, no formula has been calculated to determine the volume of water it filters. In order to determine the true depth of the net, when



the rope shows that it has not descended vertically, the following simple method used by Apstein is of great service. It can also be used to determine the depth at which a dredge or any other piece of apparatus is trailing. The apparatus consists of a piece of plate glass about a foot square and ruled at regular intervals of one centimetre with horizontal lines. A flat strip or ruler of aluminium is fixed at one corner by a pivot passing through the plate glass, so that the ruler can be made to describe an arc over the glass plate. The rule is divided into centimetres and perforated along the middle line at each centimetre mark, so that when it is standing vertically, the perforations for each centimetre mark lie exactly over the corresponding horizontal lines on the glass. Both the lines on the glass and on the rule are numbered 1-2, 3..., similarly, but each space can be used to equal 10, 20 or 100 metres, as the case requires. If the net has been drawn somewhat out of the vertical, it is only necessary to hold the glass plate up so that its upper and lower edges AB, CD are perfectly horizontal and so that the net rope from the pulley to the water lies between the observer and the light. Supposing now that 80 metres of rope have been paid out, let each division on rule and glass equal 10 metres, then the rule is moved until it is parallel with the net rope as seen through the glass plate, and the line on the glass plate intersected by the 80 metre mark on the rule will be the true depth of the net. Let us suppose a certain station has been reached where it is desired to make a quantitative catch. The ship should be anchored so that it remains in the same position during the work, and all fear of towing the net in a horizontal position will be done away with, unless a strong current is present. This is most important where it is most difficult to perform, namely, where the depth is

considerable and some time elapses during the lowering and raising of the net from the bottom. The net is swung over the ship's side, supported by its wire rope, which passes over the "accumulator pulley" and then over the recording apparatus on deck to the winch. When all is in readiness, word is given to lower the net. An assistant should note the moment that the *mouth* of the net reaches the surface of the water, and shout a word of warning. This is the zero, and at this moment another assistant who is observing the recording meter takes down the figures exposed. To these figures the required depth should be added, and then the net can be lowered until the meter gives the necessary numbers.

When the net has been hauled again to the surface, it is held over the ship's side and well washed down with a strong stream of water. This is most important, as a great quantity of the catch is often lodged under the mouth-piece lower ring. A strong stream of salt water from the hose is by far the best method of washing the catch down into the filtering bucket, and if no steam hose is available, a small hand pump worked on the deck is better than using buckets. A separate filtrator is unnecessary. After the net has been well washed and the water allowed to run out until only a little remains in the bucket, this is unscrewed and the catch can now be removed and fixed.

#### PRESERVATION OF THE CATCH.

When preserving the catch it is advisable to remove as much sea water as possible, and to use a reagent that will be simple in application and render the organisms easy of identification. For this purpose 90 per cent. of alcohol is used directly, it having proved the most convenient for ordinary purposes in quantitative work. It

is applied as follows:—The filtering bucket which has been unscrewed from the net is inclined so that what little water remains in it lies over the silk. By carefully tapping or rubbing the latter, this water can be got rid of; but in doing this great care must be taken that the water, and consequently part of the catch, does not run over the edge of the bucket.

The filtering bucket is now held over a glass tube or bottle, the tap opened, and the whole catch washed out by a strong stream of alcohol directed from a wash bottle directly on to the organisms on the *inside* of the bucket. By this means the catch is easily removed by the fixing fluid itself, the sea water is reduced to a minimum, and the catch is fixed and put in its preserving fluid as soon as possible after leaving the water, by means of one operation. The bottles can be stored away and taken to land for further investigation. To run the contents of the filtering bucket into salt water and carry to land is, even when only an hour intervenes, not at all advisable and, of course, impossible on a long cruise.

#### THE ESTIMATION OF THE CATCH.

There are two methods at present in use by which the plankton tables are constructed. One is a simple method of estimation by examining the catch under the microscope, noting down the forms that occur and denoting their frequency by letters such as *c. c.* (very common), *c.* (common), *+* (neither common nor rare), *r.* (rare), *r. r.* (very rare). This method is still the most general one in use. The other method is that carried out by the Hensen School, and forms as essential a part of the quantitative work as the nets themselves. By this latter, the actual organisms present in a known fraction of the catch are counted. Since the first method still is

the most common, it will be necessary here to emphasise its great defects and almost worthlessness for quantitative work when not supplemented by the other. Suppose that one has a certain plankton catch obtained by a vertical haul of the net through 40 fathoms, that the catch has been estimated, and according as the various forms are relatively frequent or rare, they have been designated with letters as above described in the tables. Now we will assume that a second catch taken in another place from the same depth has all the organisms present in the same relative proportions as in the first, but in double or treble the quantity. This would make no difference whatever in the tables, the relative frequencies still remain the same, even though a form which is represented by "rare" in both catches may be present two, three, or four times as many in one catch as in the other. Thus the tables could not be directly comparable for quantitative purposes. We have, however, assumed here that the constitution of both catches was identical—a thing of almost impossible occurrence. Let us assume now that the constitution varies, and that three catches are taken (an example given by Apstein), as one makes a voyage out from the coast, and that these are estimated by both methods. By counting, the first is found to contain 50,000 *Ceratium fusus* and great masses of the diatom *Skeletonema*. In the second catch, taken further out, there are still 50,000 *C. fusus*, but the diatoms have disappeared. At the third station *C. fusus* still remains at about the same number, but *Ceratium macroceros*, up till now rare in the catches, appears rather abundantly. Now, an investigator who simply estimated the relative frequency of these organisms would state that *C. fusus* was very rare in the first catch (since they were overshadowed by the great masses of diatoms), common in



the second catch (where in proportion to the diatoms and other forms they *seemed* abundant), and again very rare in the third catch (where the *C. macroceros* has appeared so abundantly). In reality, however, the number of *C. fusus* has remained the same. An observer estimating by relative frequencies would have constructed a table and curve showing a great increase at Station 2, and then sought for an explanation of this increase, which in reality did not exist. If plankton tables are to be constructed for a large sea area, in order to compare the plankton at different places under different conditions of salt contents, temperature, currents, and other changing conditions in the sea, *quite false results* would be obtained from the method of estimation without counting.

Moreover, the reliability of such estimations is not good. In order to determine this, Apstein and one of his colleagues took four catches and first simply estimated them in the usual way, and then counted and estimated by the Hensen method (14). A section of the table will show the results. The first column gives Apstein's estimate, the second gives that of his colleague, and the third gives the true number present as found by counting the various forms present and then using letters derived from the frequencies determined by the counting, in order to compare with the other two columns.

	A., by estimation.	R., by estimation.	By counting method.
Rhizosolenia alata .....	r	+	rr
„ semispina .....	...	rr	rr
„ shrubsolei .....	c	...	c
„ stollerfothi .....	r	r	+
„ styliformis .....	+	+	c
Ceratium tripos .....	cc	cc	c
„ longipes .....	cc	+	cc
„ furca .....	+	c	cc
„ fusus .....	r	r	+
Cyphonautes .....	...	r	r
Limacina .....	r	+	c
Molluscan larvae.....	+	+	c
Oikopleura .....	c	+	c

Eighty-one species were estimated in the catches, and in only one case did both estimations agree with the numbering. It was possible for three things to happen: (1) For both estimations to agree with the numbering; (2) for estimation and numbering to give parallel results, but not be alike; (3) for estimation and numbering to be contrary to one another. Only one species agreed in every respect, 13 species gave parallel figures, and in 67 species the estimations and numbering were contrary. Thus the personal error forms an additional source of failure in the simple method of estimating a catch by the frequencies, whereas by the counting method two observers will practically agree, if both count the same catch. Thus, for tables to be of any scientific worth in comparisons made to show the dependency on hydrographical or other conditions, or of the various forms upon each other, the catches must be made quantitatively and the unfortunately tedious method of counting followed.

A very detailed account of the apparatus and method of counting has been given by Jenkins (12), but the method as at present carried out for general work will be briefly described here, in order to give the complete procedure. The first work consists in the estimation of the volume and the construction of curves to illustrate this. In most cases, unless the plankton is caught on an expedition lasting some months, the volume estimation will be made on shore. If it is required to estimate the volumes of the catches on board ship, the usual swinging table is required. The catch which has been fixed and preserved in alcohol is allowed to stand, and the alcohol decanted and its place taken by distilled water. The catch in distilled water is now brought into the measuring vessel. If distilled water is not used instead of the

alcohol, the volume will be quite inaccurate, because a precipitate forms from the salt water that has been round the organisms when first fixed. This in appearance is like a diatom deposit, and the volume of a catch may be reduced to one-third by transferring from alcohol to water, owing to the removal of this precipitate. Ordinary measuring glasses are of no use for measuring accurately small catches. A special make of glass tube is used, the bottom of which is drawn out into a cone ending in a blunt point, so that a small volume of catch will occupy a considerable depth of this narrow termination. The plankton catches in distilled water are transferred to these tubes and allowed to settle for 24 hours. A mark is then made with ink on the outside of the tube at the level to which the sediment attains, and the catch is again removed. The quantity of water measured out by means of a burette, which takes up the same space as the sediment, will be the volume of the catch.

This volume estimation is necessarily very rough, since, especially if diatoms be present, a quantity of liquid remains between the organisms and causes the sediment to appear much greater in volume than it really is.

Having found the volume of the plankton in cubic centimetres, it is multiplied by 80 (for the Middle Apstein Net pulled up  $\frac{1}{2}$  metre in 1 second), and this gives the volume present in a column whose area is one square metre and whose length is the distance through which the net has been hauled. For purposes of comparison and the making of curves, the average volume per cubic metre is generally reckoned from the above.

The next division of the work consists of counting the organisms. For general use with the Middle Net the catch is brought into 50 c.cm. of distilled water. If the catch is very large a further dilution may be neces-

sary. This 50 c.cm. with the catch is placed in a shaking flask, and, by means of the plankton pipettes, 0.1 c.cm. of the fluid is withdrawn after carefully distributing the organisms by thorough shaking.

It is necessary here to emphasise the use of these special pipettes devised by Hensen (**1** and **5**), since no other apparatus will allow of the accurate abstraction of such small quantities.

First, 0.1 c.cm. is taken and removed to the counting plate under the microscope, and the organisms counted. A sheet of paper is used with the names of the species to be counted, and, as each form is passed over, a stroke is placed opposite the name on the paper. Since 0.1 c.cm. is  $\frac{1}{500}$  of the 50 c.cm. to which the catch was diluted, the numbers must be multiplied by 500 to give the full number for the catch, and then from this the number per cubic metre is calculated. In general use only one plate is counted with 0.1 c.cm., and then a pipette abstracting 0.2 c.cm. is used in the same way, but only those organisms occurring in very small numbers, or doubtful in the first plate, are counted in the second, so that whereas 50 species may be counted in the 0.1 c.cm., this number may be reduced to 12 in the 0.2 c.cm. Following these two plates, 0.5 c.cm. and then 1 c.cm. are taken, and finally the rest of the catch for the larger forms and for rare forms is counted, making a total of five plates. When greater accuracy is required, more plates are counted for the same pipette until the difference between the number of organisms on the last counted and the average number for the previous plates is less than 5 per cent. If an organism is required for a preparation or for further observation, it can be removed from the numbering plates by very small capillary pipettes about two inches long.



During the last few years it has become obvious that the catch with the fine meshed bolting silk only gives an incomplete sample of the plankton present in the sea at any given place. Kofoed (8) and Lohmann (11, 13 and 18) have both emphasised this error, but it is to the latter that we are indebted for a complete investigation of it and of the means of overcoming any failings in this direction. In an important paper, published in 1902, an account of the comparisons between various methods for catching the smaller plankton organisms was given in detail. The subject has since that time been further investigated, and whilst writing this a detailed and very elaborate account, bringing the plankton work up to date, is going through the press (18). By the kindness of Prof. Lohmann, I have been able to see his tables and read through the proofs of this work. Hensen's method rests on two hypotheses:—(1) That the pelagic organisms in the sea inside a region of *like conditions of existence*, with regard to time and space, are so equally distributed that by the investigation of relatively small quantities of water, a sufficiently accurate picture of the quantity and quality of the plankton for the whole region can be obtained. (2) That the apparatus used for these investigations, namely, the Hensen net, even with its uncontrollable errors, gave essentially a true estimate of the plankton. The first hypothesis will be discussed later. With regard to the second, there is the possibility of the net failing to catch an important part of the plankton, through small organisms passing through the meshes. Hensen himself in 1887 stated (1) that if he allowed the water filtering through the silk net to pass through close silk, filter paper, &c., and investigated the residue, many diatoms, peridinians and silicoflagellates would be found to have passed through the net. He believed, however,

that the influence of this loss, on the constitution of the catches and the results given by numbering, was of no essential importance, since the mass of the forms slipping through was only small in comparison to the quantities caught by the bolting silk; and, in any case, Hensen gave his numbers as a *minimal value*, recognising that a loss must occur. Kofoed in 1897 (8) through new investigations in the fresh waters of North America came to the conclusion that the loss which enters into the results, when nets of "Müllergaze" are used, was much greater than Hensen had supposed. By using filters of hardened paper, he demonstrated that only 2-50 per cent. of the organisms were caught by the net. Lohmann (13), when investigating the Appendicularia, also found that the quantity of small forms going through the net must be of far greater importance than was formerly supposed. Nothing shows the loss more distinctly than the investigation of the food of the plankton organisms themselves. One finds in their alimentary canal the remains of the smallest diatoms, Peridinians, Coccolithophoridae and Silicoflagellates, of which an ordinary net used in the same water in which the "devourers" (Pteropods and Appendicularia, &c.), lived, would contain none or few. As showing the importance of this loss, Lohmann mentions the fact that the Coccolithophoridae, which play a great part as food for the plankton animals of the North Sea, are almost unrecorded in the tables when bolting silk nets are used.

The most favourable organism on which to study the food of the plankton animal is the Appendicularian, which does not take food directly into the alimentary canal, but secretes a special structure, the "house," for the purpose of catching its food. This is a perfectly transparent structure, and under the microscope can be

seen to contain the uninjured and living food before it passes into the alimentary canal. Here in this filtering apparatus of the Appendicularian are numerous naked Rhizopods and Gymnodineae, together with smaller skeleton-carrying Rhizopoda, completely absent from the net catches. It is obvious, therefore, that if a complete knowledge of the plankton is to be gained, other methods must be applied.

It was assumed that the loss of plankton by the use of No. 20 silk in the net was unimportant, and that the real masses of plankton in the sea might be only 2 to 3 times greater than the figures given by the net. This would certainly be of no great importance if only the volume or weight of the plankton present was required without any reference to its constitution. If one requires however, the chemical constitution, it is quite incorrect, and this applies further to the qualitative and quantitative counting method, because the animals and plants in the catch will occur in quite different relative proportions from the true conditions present in the sea. Since the mesh work of the net itself has a large area, many of the small forms which could pass easily through the meshes will be caught on the net tissue itself; and this will give a more deceptive appearance of reliability than if these forms had altogether escaped.

Again, the fractions of these small forms caught is not always the same, because if the sea contains a great number of diatoms (as *Chaetoceros*), the meshes of the net will be gradually filled up, and the spines interlocking will cause the net to act as a much finer filtering material and hold back many species which would otherwise slip through. This accounts very often for the large catches with the nets, when diatoms are very abundant. By comparison of the net catches with the other quantitative

catches made by the apparatus to be described below, it has been found that the Metazoa, with few exceptions, are completely or sufficiently caught by the plankton net, whilst of the Protozoa only a few large forms, *Noctiluca*, *Ceratium tripos*, &c., or species with long spines, will be obtained. In fact, the number of individuals present in the sea is from 5 to 100 times greater than is demonstrated by the net, and the species which form this loss are not of "no importance," but are the chief forms of food for the larger species, and therefore of great significance in the metabolism or see-saw of life in the ocean. If, therefore, the Metazoa or larger Protozoa and Protophyta only are to be studied, the net can be used as the best instrument by far for the capture, whether for quantitative or qualitative purposes. If a complete investigation of the plankton is to be made, and the relation of larvae to adults and food to the eaters of it are to be considered, other kinds of apparatus must be used. Of these, the most important is the Pump and Tube, by which water is pumped up to the boat and later is filtered. In shallow water, and up to 100 metres deep, the net can be more or less supplanted by the pumping method, but, unfortunately, for greater depths, and for regions where there are strong currents, the pumping method is hardly applicable.

#### PUMP, TUBE, AND FILTER METHOD.

Essentially the method consists in the pumping up of a vertical column of water, which is filtered on the vessel or, later, on shore. An indiarubber tube of sufficient length for the deepest regions is required, and this is lowered vertically in the water by means of a rope attached to the lower end, and in the same way is slowly pulled up, whilst at the same time the water is pumped out of the upper end by a small brass pump.



By lowering the tube it fills gradually with water out of the various depths through which the lower end sinks, so that finally it contains a water column, consisting of water from all depths between the surface and the lowest point reached. When the tube is again slowly raised through this column to the surface, it is once more filled by water from each layer. Thus by repeatedly lowering and raising, whilst the pump is worked, any quantity of water may be obtained, representing a vertical column whose height is that from the lowest point reached by the tube up to the surface and whose other dimensions can be reckoned directly from the volume of water collected.

The water in the sea will naturally rise in the pump tube of its own accord until it attains the same level as the surface. It is only necessary, therefore, to use the pump to lift the water from the surface of the sea into the boat, and a small pump is accordingly quite sufficient. It is even possible in a boat with a deep bottom, where the upper end of the tube can be placed lower than the surface of the sea, to siphon up the water, but usually, owing to the motion of the boat, this method is not successful. The whole length of the tube should be fastened to a rope which will bear its weight. If currents are present, the rope and pipe must be kept vertical by means of a sinker.

A very simple and cheap arrangement was constructed and used by Lohmann in the Mediterranean (13), so that the simple turning of a windlass both worked the pump and pulled up the tube. Thus the rate of pumping and the pulling up of the tube were always in the same relation, however quickly the windlass was turned. Moreover, the direction in which the windlass was turned had no effect on the working of the pump,

which continued to raise water whilst the tube was either lowered or raised. Since it is questionable whether this method of sucking up the water would have an effect on the catch, the entrance of the plankton and its passage up a tube was observed by Lohmann by using a glass tube. It was distinctly seen that the organisms in the centre of the tube ascended more rapidly than those against the walls. This difference in the current is, however, of no importance for the equal raising of the whole water column, because from each section the same quantity of central and peripheral water will be taken up respectively. It was noticed that some of the large animals were sensitive to the streaming, and Copepods, for example, moved energetically against the current. If, therefore, the current is slow, it is possible for the larger forms to move out of the tube, but, since the average speed of the current is 57 cm. per second, this is impossible; and any loss occurring when the pumping method is used applies only to the destruction of fragile forms in the filtration.

The water must be filtered, either on the ship or when conveyed back to the laboratory. The latter is probably the more simple. The water is pumped into large sulphuric acid "carboys" of about 28 litres contents, and a  $\frac{1}{2}$  litre of commercial formol is added so that a 2 per cent. solution results, which suffices to kill the organisms and to fix them. The filter is simply hardened paper, which is folded into a cone and is held in a zinc funnel of about 50 centimetres diameter at the mouth. It is best to construct an arrangement so that the water can run from the carboys into the filter at the same speed as the latter filters. The whole can be then left to run of its own accord, with but an occasional glance to see that the filter does not become stopped.

The filter is carefully washed down towards the point of the cone when all the water has been filtered, and this is perforated by a pointed glass rod, whilst held over a bottle for the reception of the catch. The filtrate is then carefully washed through the perforation by means of a wash bottle provided with a strong indiarubber ball, in order to get a powerful current. The original volume of water collected being known, the catch as now obtained can be diluted and portions extracted for counting as explained above.

By fishing with the net and also with the pump and tube simultaneously, or directly after one another, and comparing the results, it is possible to determine the loss by the net due to its inability to retain the smaller forms.

If, however, exactly like methods are employed at the same time and place, and close to one another, the catch is different. This divergence, due to an irregularity in the distribution of the organisms in the sea, has been emphasised by Herdman and will be mentioned later. It must be borne in mind, therefore, when comparing the *unlike* methods, that a certain irregularity in distribution already exists. After reckoning the volume of water filtered by the net and reducing the number of organisms found in the whole catch to the number present in a volume of water equal to that collected by the pump, it was found by Lohmann that in the case of Copepod nauplii the net lost 74·5 per cent. This is a very important constituent of the plankton fauna. Other organisms were present in 1,000 litres of water in the following numbers:—

	Silk net	Pump, tube
	No. 20	and filter.
Globigerina .....	250	2,125
Radiolarians.....	2,350	3,860
Cystoflagellates .....	20	20
Tintinnidae .....	475	19,900
Naked ciliates .....	some	35,300

The Radiolarians were caught almost equally well by the net owing to their shape and large spines. The Tintinnidae could easily slip through when meeting the net in the direction of their long axis.

For Diatoms and Peridinia, &c., the following results were obtained:—

	Silk net No. 20	Pump, tube and filter.
Skeletonema .....	...	418
Coscinodiscidae .....	141	6,444
Rhizosolenia alata .....	1,143	4,013
Chaetoceros Ehrenbergi.....	44,317	149,793
Ceratium tripos .....	about equal in each.	
Peridinium divergens.....	72	317
„ globulus .....	15	1,190
„ pellucidum .....	5	1,089
Coccolithidae .....	28	11,267
Dictyocha .....	54	6,241

The comparisons for the Protophyta show, therefore, that the constitution of the plankton catch was completely altered by the use of the pump and filter. Out of more than 2,000,000 plants only 110,000 were caught by the net with No. 20 silk, and 9,000 animals out of the one-third million caught by the pump and filter.

The actual numbers have, however, not so much value, because the smallest organisms give the largest numbers for the loss. If the mass, however, be calculated it is found that the pump and filter gave 52·4 c.cm. as total catch out of 1,000 litres, whilst only 21 c.cm. were caught by the net.

Hence the constitution of the plankton, formerly determined solely by net catches, must contain greater errors for many forms than were supposed.

#### METHOD OF INVESTIGATION FOR THE SMALLEST ORGANISMS.

It has been demonstrated by several observers that many of the small and fragile forms, without skeleton, are either destroyed completely during the filtration or



pass through the filter, so that even the method with pump and filter fails to give the smallest forms and also the bacteria.

This loss is easily seen by an investigation of the filtrates from a hardened paper filter, which reveals the fact that as much as 26 per cent. of the Gymnodineae and the same per cent. of naked Chrysomonads can pass through; and a much greater percentage of bacteria would be found to have done so.

Of even greater importance than this loss is the fact that many softened fragile forms are killed by the filtration, and Monads, Amoebidae, and small Gymnodinae will be absent for that reason from the filter catches. Moreover, it is very difficult to recognise most of these forms when fixed and preserved, and, therefore, for these forms alone it is necessary to use other apparatus which does not require any filtering mechanism and which will allow of the organisms being studied in the living condition.

The apparatus consists of (1) a means for procuring samples of water from different depths, and (2) a centrifuge. By this method small water samples can be taken and examined from the various parts of a water column down to the greatest depths in the ocean, and from these, by interpolation, the average number or volume of organisms present in the complete vertical column can be calculated.

A "Krümmel" water bottle (fig. 4) is the most satisfactory for the purpose of obtaining water samples. It is already made sufficiently large to bring up three litres of water from any depth required, which is sufficient to allow of a portion being used for the determination of the hydrographical conditions—an absolute necessity in plankton work. The water bottle is lowered open and closed at the required depth by a falling weight, sent

down the rope from the surface. The water required for the centrifugal investigation is taken from the water bottle, received in glass-stoppered bottles and placed in a cool and suitable place until the laboratory is reached: the examination should take place as soon as possible after the catch is made.

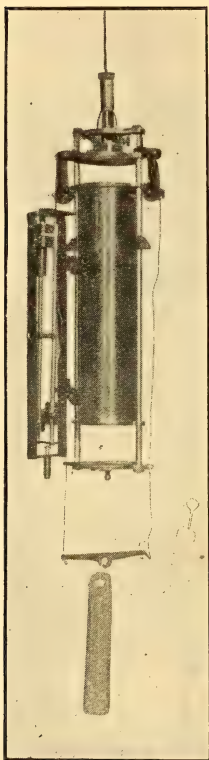


Fig. 4.—Krümmel water bottle.

The employment of the centrifuge for this work was first suggested by Cori (6), but it has not been much used, as it was pointed out that the action on various organisms is selective, and the sediment is therefore not in its constitution a true sample of the plankton present. This selection does not come into play if the organisms are dead and in a preserving fluid that is lighter than water, consequently Kofoid has used the method for catches preserved in alcohol. Dolley (16), by using a very powerful centrifuge which he termed the "Plankton-okrit," and which gave 8,000 revolutions per minute, had complete success in the sedimentation of living plankton. Other American workers, also, have used this method, and have found that for accuracy of determination it far exceeds all other methods at present employed.

Kofoid, however, raised the objection due to its selective influence, and found that many organisms would not form a sediment. One must remember that no method will be accurate for all forms, and none of the

methods here described will alone give an accurate sample of *all* the forms present in the plankton.

Lohmann has used with success a centrifuge which carries four glass tubes and which gave easily 1,300 revolutions per minute when turned by hand. He found that 9,000 revolutions, in seven minutes, were usually sufficient.

For the investigation of the living forms, samples of only 5 to 15 c.cm. are taken. The tubes for containing the sample, on the centrifuge, are small cylindrical vessels, with the point drawn out slightly to form a cone-shaped end, in which the material will form a well-defined sediment.

After the completion of centrifugation, most of the water can be poured away, and the sediment remains undisturbed with the water that fills the conical end. By means of a pipette, the sediment, through repeated sucking up and forcing out, is finely distributed in the water remaining, and is finally completely sucked up and transferred to the glass numbering plate used with a specially constructed microscope stage. This is much smaller than the numbering stage for the large net catches, is comparatively cheap, and can be fitted to any microscope.\*

The conical end of the tube is now washed out with a very little water (some of that originally poured off), and this is added to the main part of the catch on the glass plate. The whole catch should form only a single drop, such as can be covered with an ordinary 12 mm. cover glass.

If the water contains many flagellates and ciliates, the counting of such rapidly moving organisms is impossible. The cover glass should then be held over

\* Zwickert, Optician, Kiel, is the maker of this stage.

osmium vapour for a short time before being placed on the drop of water and sediment, which is sufficient to cause narcotisation. When high powers are used, it is impossible to count the organisms in the complete area of the drop. In this case only a fraction is counted, in the following way. The glass counting plate on which the drop rests is crossed by a series of parallel lines running in one direction, from the observer. If the number of spaces between the lines, which are covered by the whole deposit when the cover glass has been applied, is divided by five, that gives the spaces in which the organisms should be counted in order to arrive at one-fifth of the total in the catch. These spaces counted should be equally distributed over the whole area, so that an average can be obtained. It is best first to count the organisms in one-fifth of the mass with a high power for the smallest and most frequent forms, and then, under lower magnification, the whole mass for the larger and less frequent.

It is well also to take another quarter of a litre of the same sample from the Krümmel bottle (fig. 4) and add formaline to make a 1 to 2 per cent. solution. After this liquid is partly removed from the catch by filtration through very fine filter paper, the residue can be centrifuged and compared with the centrifuged samples of living forms. The amount of water taken for the centrifugation of the latter must depend on the number of organisms present. If 15 c.cm. of water are first taken and centrifuged, and too many organisms are found for an easy count, then it should be discarded and a smaller quantity taken.

The extremely small quantity of water taken for these samples is astounding and might be considered insufficient for two reasons:—First, that not enough animal



and plant life are present in such small volumes; and, secondly, that they are absurdly small for quantitative estimations of a column of water or for finding the true conditions in the area where the samples are taken. This does not, however, seem to be the case; and with regard to the first point, it is surprising what a mass of material 15 c.cm. of water gives with the centrifuge, so much that Lohmann had often to take less. The second difficulty is also only apparent, because when the Hensen plankton nets are used the sample of water taken for counting bears an equally extremely small relation to the quantity of water that has passed through the net. The only real difference between the two former methods, the net and pump and filter, and this method is, that in the former the plankton is collected from relatively large masses of water, and small quantities are taken out of this as samples for counting, whilst by the centrifugal method the small quantities are taken directly from the sea. In stating this, however, we are again confronted by the doubt as to the equal distribution of the plankton in the sea, which will be mentioned later. Lohmann thinks that the distribution is sufficiently like to allow of such small samples being reliable guides to the quantitative constitution of the plankton.

In order finally to calculate the average number of organisms present in a column of water, from which various samples have been taken at various depths, the following formula should be used. Assuming that the samples A, B, C, D are taken at increasing depths, separated by the distances  $a$ ,  $b$ ,  $c$ , then  $\Delta$  is the average for the column.

$$\Delta = \frac{Aa + B(a + b) + C(b + c) + Dc}{2(a + b + c)}$$

If one wishes to make a complete investigation of

the plankton, either qualitatively or quantitatively, one must use all the three above methods side by side. If only a definite part of the plankton is to be studied, then the method must be chosen to suit the case. For large crustacea, fish eggs, and medusae and other large plankton forms occurring but seldom in the water, in comparison to the Copepoda and smaller forms generally, the large Hensen net described by Jenkins should be used, to work through much larger quantities of water. For the main constituents of the plankton, the Copepods, Ceratium, and, in fact, for general use, the Middle Plankton Net of Apstein is to be preferred. This has been the chief instrument used in German investigations, and holds its place because of the ease of working and the general applicability. It must be borne in mind, however, that when these nets are used there is a considerable loss, as has been shown above, and, therefore, when possible, the use of the net should be replaced by the pump, tube and filter. In fact, in water of moderate depths, and shallow water, the pump method is "the" method for plankton investigation, and the net and centrifuge should be used only to complete the results when the greatest possible accuracy is required and the complete constitution of the plankton is to be discovered. The points against the pump method are the difficulties encountered in deep water or when there is a strong current, together with the greater time that is required for pumping and filtering.

There is another possible method for arriving at these results, which could be applied to the greatest depths, and in comparatively stormy weather. It is to use a water bottle for collecting a volume sufficiently large to allow of its being filtered and examined in the same way as the water from the pump. In this way,

however, the contents of a vertical water column would have to be calculated from the samples taken at various depths. For this purpose, too, it would be necessary to obtain more water than is brought up by the bottles now in use. The Krümmel bottle as now used by hydrographers has three litre contents, and there should be no difficulty in increasing the size to five litres, which would give a sufficiently large sample.

#### OTHER PLANKTON APPARATUS USED FOR QUALITATIVE WORK.

The apparatus above described is intended for the quantitative estimation of the plankton in volume, chemical constitution, or by the counting method of Hensen. For mere purposes of qualitative investigation the procedure is naturally much more simple. The net described is, in any case, of great use as a vertical net, and would completely supplant the pump and filter, whilst the centrifuge would be used to catch organisms that pass through the net. Under special circumstances, however, other nets are used, which are coarser, and have their special use according as they are for surface or deep work, and for small, large, or very large organisms. Again, it is sometimes desirable to investigate the plankton of areas over which the ship is passing at a considerable speed, and for this purpose other devices are necessary.

For general use in qualitative work there is the ordinary small tow-net, well known at all biological stations. This is constructed out of bolting silk, and has the same conical shape as the vertical net, but does not have a mouth-piece as described for the quantitative nets. No calculations can be made as to the quantity of water it filters. These nets are generally used for

horizontal fishing, and should be made with No. 20 silk for smaller organisms, and with No. 12 or No. 3 when larger forms are specially required, since with these latter silks more water will be filtered in a shorter time, and the catch will be free from the masses of small diatoms, which are not wanted.

All plankton nets should be fitted with a metal filtering bucket attached to a brass ring, which forms the base of the net, by means of a screw attachment, or by the simple device of a bayonet joint. This bucket consists simply of a brass cylinder, the size varying according to the size of the net; the lower end is closed by a piece of silk of the same mesh as that used for the net, and attached to the brass cylinder by means of a clamp ring.

When the net has been used, it is only necessary to wash it down with a few pails of water thrown on the outside, and to unscrew the bucket with the catch. If time is short, and the catch has to be preserved as soon as possible, the silk itself can be removed from the bottom of the bucket, rolled up, and dropped into a bottle of alcohol without removing the organisms; a new piece of silk is then placed on the bucket and it is ready for further use.

For fishing pelagic eggs, young larval stages of fishes, or when large catches are desired for histological or anatomical work of large plankton organisms, such as Medusae, very large Copepods, Sagittae, pelagic worms, &c., the German "Brutnetz" is a very successful instrument. This, as the name implies, was constructed for fish eggs and larvae. It is much cheaper than the silk nets, since it is constructed of "cheese cloth," or of good canvas. This is simply a conical net about three metres long, the mouth of which is kept open by a wooden ring of cane 80 to



90 cm. in diameter. About one metre from the mouth the net is attached to a second wooden ring, to one point of which is attached an additional rope from the ship, so that when the haul has been made the net may be rapidly pulled up edgewise without offering opposition to the water. The apex of the net where the usual bucket is attached has a diameter of 10 centimetres.

A modification of the "Brut" net, called the "Scherbrutnetz," has been constructed to allow of the application of such a net as the former to the collection of the plankton from deeper layers. The essential feature is a strong galvanised iron plate, hinged, as seen in fig. 5,

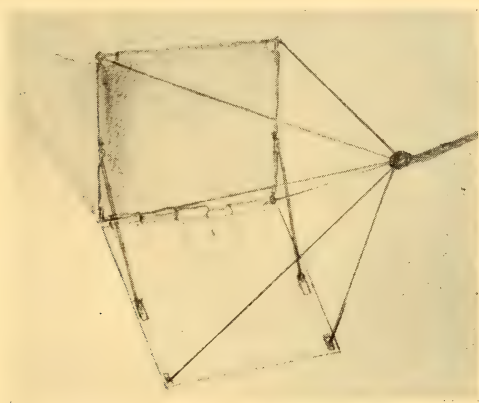


Fig. 5.—The "Scherbrutnetz."

to one side of the square mouth of the net. This "shear" board is, however, not allowed to move freely, but is fixed so that it makes an angle of  $125^{\circ}$  with the plane of the mouth of the net.

When this net is hauled the water presses against

the "shear" plate exactly as on the otter boards of the otter trawl, or like the wind on a "kite," causing, in this case, the net to sink in the water. Knowing the length of rope allowed to run out, the true depth of the net can be easily found by using the Apstein apparatus already described and measuring the angle the rope makes with the horizon.

A still larger net than the "Brut" net is sometimes desirable where very large catches are required of the larger plankton forms from deep water. For this purpose there is the so-called "Knüppel" net (fig. 6), which is

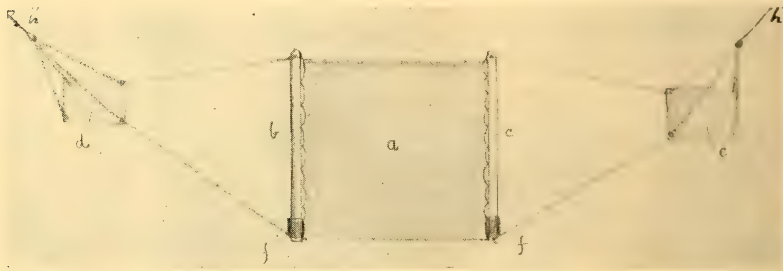


Fig. 6.—The "Knüppel" net.

worked on the principle of the otter trawl. The Knüppel net can only be worked satisfactorily when a fair sized vessel is available with a steam winch. The net which I have seen in use has the following dimensions. The net itself is made of strong canvas and is about 15 to 20 feet long, the mouth is square, each side of the square having a length of 8 feet, and each of the mouth edges is formed by a broad piece of sailcloth, to which the filtering canvas is sewn. The apex of the net is as usual fixed to a metal bucket, in this case about 9 inches in diameter. The two vertical sides of the mouth of the net are fixed at intervals to two stout poles (fig. 6, *b.* and *c.*) 9 feet long, and provided at the lower end with a heavy lead sinker

(fig. 6, *f. f.*) in order to keep them vertical in the water. Each pole is attached by two strong ropes, fixed to the upper and lower ends respectively, to the "otter" boards (fig. 6, *d. e.*). The ropes are about 12 feet long, and represent the "foot rope" and "head line" of the otter trawl. The otter boards are strong wooden structures bound with iron, and measure 4 feet by 2 feet. When the net is lowered it sinks, owing to its weight, and the pressure of the water forces the two otter boards outwards, thus pulling the two vertical poles as far apart as possible, and in this way the mouth of the net is kept open. This net can be used satisfactorily at very considerable depths.

There remains to be described a very convenient and simple little instrument by which catches can be made whilst a vessel is travelling at a considerable speed, and, consequently, any changes in the nature of the plankton between two stations can be followed without interfering with the progress of the steamer. Several instruments have been invented for this purpose, but it will only be necessary to mention here the "Plankton Röhre," which was invented by Apstein and has not yet been described. It has the great advantage of being simple, and so small that it can be very easily carried about with one, so that plankton catches may be made on a sea voyage other than a scientific expedition. Fig. 7 shows the external appearance of the instrument. The Plankton Röhre consists simply of a brass tube 25 cm. long, one end of which, however, is not of the same diameter as the rest of the tube, but forms a truncated cone, making the mouth opening of the tube very narrow. The diameter of the cylindrical section of the tube is 3.5 cm., and the length 22.5 cm. The conical mouth-part is 2.6 cm. in length, and the opening is only 1 cm. in diameter. This narrow opening

is for the entrance of the water, and is, therefore, the front end. The other end of the tube is closed by the filtering apparatus—simply a piece of No. 20 bolting silk, or coarser, if required, which is fixed in the usual manner by a clamp ring.

To one side of the tube is attached a heavy strip of lead (fig. 7) to keep the instrument from being pulled out of the water. This will consequently be the under side, and to the opposite and upper sides of the tube, at the front end of the cylindrical portion, two ring attachments are screwed, by which the whole apparatus is

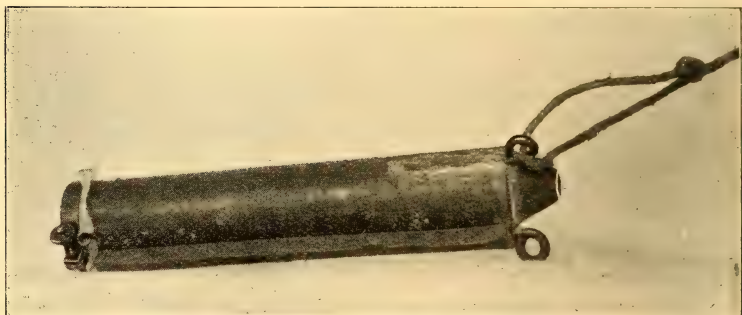


Fig. 7.—The "Plankton-Röhre."

fastened to the hauling rope. The action of the instrument, when pulled at a considerable speed, depends on the small area of the opening, which allows but little water to enter, and therefore there is but little strain on the silk tissue, so that this is not torn nor are the organisms damaged. I have seen it used successfully at a speed of eight and a half knots. One disadvantage is that very small catches are obtained, even when towed rapidly for a quarter or half an hour, but since the apparatus was not intended for obtaining large quantities, this does not detract from its usefulness.



## RESULTS OF THE PLANKTON WORK AND ITS AIMS.

I propose now to discuss briefly some of the results obtained by the quantitative method, and the present position of the work. The first ideas came from Hensen's investigation into the distribution of the eggs of the plaice in Kiel Bay. These are planktonic eggs, which float as long as the salt contents of the water does not sink below 1.78 per cent., and this is seldom the case in the West Baltic. It became evident that these eggs extruded at many spawning grounds, must necessarily distribute themselves widely, and the longer they remain floating the more movement will take place and the more equal the distribution will become. On this equal distribution of the plankton particular stress must be laid, because it forms the foundation on which the value of the quantitative work depends. The investigation of these fish eggs led to notice being taken of the other planktonic organisms, and, finally, Hensen says—"The sea has its yearly production in animals and plants, just in the same way as a garden or field. For the land, it is an almost impossible problem to work out this production, because even if one, with extreme weariness, worked out the fauna and flora completely and quantitatively for a small area, at a short distance from this point the conditions and distribution would be altogether different, and we could never be certain that what was found in the small area would be a true sample for a large area. In the sea the conditions are quite different, the species and number remain to a certain extent everywhere constant."

Thus, with two fundamental hypotheses the quantitative method has been applied. These are, first, that the plankton organisms are equally distributed in the sea where like conditions of existence are found; and, second,

that this equal distribution is sufficiently exact to allow of relatively small quantities of water being taken as samples of the total production of the area. Amongst applications of the plankton quantitative method, the following are perhaps the chief:—

1. To estimate the produce of the sea or ocean or any particular area per year, and to compare the productiveness of different regions.

2. To investigate the dependence of the plankton as a whole, and also of the different organisms, on the hydrographical conditions, such as light intensity, temperature of the water, salt contents, currents, and, at the surface, wind and waves.

3. To investigate the relations existing between the different plankton organisms themselves, their dependence on one another, and the relation between the “eaters” and the “eaten.”

4. To investigate the reproduction of the various plankton organisms, and of others not planktonic, but whose eggs or larvae are pelagic; the relations existing between the number of eggs, the number of larvae and the adults, and the length of time occupied in the life history.

For the purpose of investigating the condition of the plankton on the high seas, the “Humboldt-Stiftung Expedition” already alluded to was fitted out, no doubt stimulated by the results of the English “Challenger” Expedition. Not all the German zoologists were in favour of the object, and Haeckel in particular wrote against it (2), arguing that the pelagic organisms were not equally distributed, but that they travelled in swarms, or at least were so irregular in their occurrence that samples taken at some distance from each other would be valueless for a quantitative estimation. He has been answered in detail

by Hensen (3). The vessel chosen for the voyage, the "National," started from Kiel, July 6th, 1889, and proceeded northwards through the Kattegat and Skagerack, and then across the Atlantic Ocean to Greenland. Vertical plankton hauls were taken at intervals on the way. From Greenland the course was directed S.W. for the Bermudas, and consequently went over the banks of Newfoundland and across both the Arctic Labrador Current and the warm waters of the Gulf Stream. From the Bermudas the course ran almost parallel to  $30^{\circ}$  N. lat., and thence across the Sargasso Sea, until the meridian of  $38^{\circ}$  W. was crossed, and the Cape Verde Isles steered for. This direction was followed further to the S.E. up to the Island of Ascension, then west again over the ocean to the Amazon's mouth, practically along the South Equatorial Current. From the latter place the vessel returned direct to the English Channel.

The series of reports by specialists on the different groups of pelagic organisms are not yet all published, and the general conclusions have not yet been put together, but from some results given by Hensen (4), it was shown that the quantitative catches agreed, as far as volume is concerned, far better than was expected, and gave still further proof of the equal distribution of the plankton. Several interesting points were brought to light in connection with the distribution. An unexpected result was that, contrary to the conditions existing on the land for both animal and plant life, the plankton was decidedly more abundant in cold and temperate regions than in the tropics. The difference in volume in the catches between Greenland and the Hebrides and those taken from the Sargasso Sea is truly remarkable.

This result was quite unexpected by those who had worked at the material rich in species, taken by the

“Challenger” in the warmer seas, but since these were only qualitative catches, no comparison could be made, and we are faced with another problem—What condition is it in the sea which makes it more favourable for life in the colder regions? This has been referred to in an important paper by Brandt (9), which should lead to further investigation.

The catches, however, made in the cooler regions are in reality much smaller than they appear, because the bulk of the organisms present are diatoms. When the volume of plankton is estimated by allowing the catch to settle down for 24 to 48 hours, an easy, but not always reliable method, it will be seen that a diatom catch refuses to sedimate as one where Copepoda or Ceratium are present. Thus a diatom catch appears to have a much greater volume than is really the case, even after it has stood for weeks. Furthermore, as Lohmann has since pointed out, the presence of diatoms in considerable quantity increases enormously the catch because the diatoms entangle themselves over the meshes of the net, and render it a much finer filtering tissue.

In the tables given in the published results of the expedition there is in one case an increase in the catch between the stations of from 5 c.cm. to 156. This sudden increase was due to *Calanus finmarchicus*; and one must evidently consider this as a swarm. The nearest land was 500 miles distant, and, after the large catch, the catches at the following stations again showed quite a small volume.

It is a well-known fact that the Siphonophora, *Porpita* and *Velella*, are found travelling in great shoals together, and in the accounts of the expedition we find that south of the Cape Verde Isles shoals were very frequently met with, amongst which occurred swarms of



Physalia, Pyrosoma, Salpa, Schizopods, Janthina, Beroë, Pteropods. Thus, one of the nets with an opening of 1.13 square metres hauled up from a depth of 500 metres 520 Pyrosoma on one occasion. The question is—What has brought these together? Neither wind nor their own motion, unless governed in some way unknown to us, could do this. At another place 5,860 Doliolum were caught in one haul of the net, as against 1,500 in all the other catches together.

Darwin, and other observers, had previously recorded the fact that long stretches of the sea were frequently met with, deeply coloured by the abundance of some animal or plant species, as, for example, *Trichodesmium erythraeum*. It is this association of planktonic organisms in swarms that is now being investigated by Herdman (17), and it will be interesting to see how far it extends. (See also 19.)

With the exceptions of some swarms, Hensen maintains that the equal distribution was never disturbed to such an extent, where the conditions remained the same, as to render the application of the quantitative method unsatisfactory. In the Sargasso Sea, for example, where there is no current practically speaking, the catches were astonishingly small, but the volume remained constant over a stretch of some thousand miles. It is possible, however, that the constitution of the catch was altered.

The results of this expedition tend to show that the ocean waters are very poor in plankton. There is a sharp distinction existing between oceanic and coastal forms; many of the oceanic species are never or only exceptionally seen near the coast, and one must visit an oceanic island in order to study them. What is the barrier to this distribution? The oceanic species are neither more frail nor more nor less active than many of the coastal

forms. This brings up the whole subject of the different conditions to which the planktonic flora and fauna are subjected in oceanic and coastal regions.

It is an important point, because though the oceanic regions are of very great extent, the waters that are of practical importance for fisheries are our coastal seas, like the North Sea, the Irish Sea, &c., where the depth is nowhere very great, but where the plankton is very abundant, and where a thorough planktonic investigation should be of considerable economic value. The bottom of these seas and all coasts is inhabited by a large and varied animal and vegetable population; the laminarian zone, for example, is probably the richest area of the earth's surface in animal life. From the Echinoderms, the Crustacea, the fish, &c., found in these shallow seas arise myriads of larval forms, which, after a pelagic life, again migrate to the bottom and continue their existence as fixed or sedentary animals. Thus the plankton of the Irish Sea is made up to a very large extent of eggs and larvae of animals which are not pelagic when adult. In one group the Crustacea, for example, there are orders like the Copepoda, which are typical plankton forms and remain, with few exceptions, free-swimming and pelagic during their whole life; while the Cirripedia, on the contrary, have the pelagic larval forms, but their adults are fixed, and therefore not constituents of the plankton.

Then, again, the Hydrozoa contain forms which alternate between a fixed hydroid generation and the free medusoid of the plankton. Certain *Nereis* species are to be found creeping about the bottom or swimming sluggishly, but when sexually mature undergo a considerable change in structure, the parapodia become modified for swimming, and the so-called *Heteronereis* stage may then be caught in considerable numbers in the plankton nets on

the surface itself. Thus the coastal plankton is made up of very diverse forms, partly always plankton, partly plankton during only certain periods in the life history. Out on the high seas, where the ocean floor is a waste as far as fixed living plants are concerned, and the water is 2,000 or more fathoms deep, the plankton contains no forms arising from the bottom. Thus the oceanic plankton is subjected to different conditions of existence, and the absence of these forms in general from our coasts is probably due to their failure to compete with the abundant pelagic life of the shallower waters. The ocean, according to the figures provided by the oceanic quantitative plankton expeditions, may be considered as a desert, receiving its life from all sides, and from this producing forms that are peculiar to it, and have in the struggle for existence been driven further out.

It is now obvious that the most important regions for the employment of quantitative methods are areas like the North Sea and the Irish Sea, or coastal water generally, where, since the plankton is of great importance as the food of fishes and contains the eggs and larvae of the latter, the results may be applied to the elucidation of problems in fishery work. It is necessary, also, to determine to what extent the plankton is dependent upon the various hydrographical conditions, and also what variations occur during the year. Since the year 1901, Great Britain, Germany, Norway, Sweden, and other countries in Europe bounding the North Sea and Baltic, have together investigated the hydrographical and biological conditions of these two areas. Grants have been given by the Governments concerned and suitable steamers provided, and an International Committee has drawn up a programme in accordance with which various stations are visited four times a year, and scientific

observations are carried out simultaneously, with the object of making a complete investigation of the whole area.

One of the most important questions is, naturally, the condition of the plankton at different places in these areas at the same time, and the variations during the year. Since at the time that these plankton investigations are carried out, the hydrographical conditions are also very thoroughly observed, there is an excellent opportunity of comparing both. Unfortunately, so far as the plankton research is concerned, the only result of these voyages four times a year has been the publishing of a great series of tables, which, for purposes of comparison, are practically worthless, since only one country, Germany, has used the counting method of Hensen. The total failure of the ordinary methods of estimation has already been discussed above, and it was then pointed out that, if the problems are to be solved, the more scientific method of counting the organisms must be adopted.

The distribution of plankton and its relation to the hydrographical conditions has, to a certain extent, been worked out by Apstein and others for the Baltic and North Sea, from the catches made on the quarterly expeditions, for the stations belonging to the German section (15). It has been found of very great importance to use the closing net, and, in addition to a vertical haul from the bottom to the surface, to divide this column up into sections, as, for example, where the depth is 210 metres, a haul is taken from 210 to 65 metres, another from 65 to 25 metres, from 25 to 5, and, lastly, from 5 metres deep to the surface. This last catch is particularly important and very often differs markedly in its constitution and volume from the others. In all probability the surface layer of water to a depth of only one metre is the layer concerned,



but, owing to wave motion, it is better to make the haul from a depth of five metres. This shallow surface layer of the sea appears to be particularly rich in plankton, and it is therefore conceivable from this how two tow-nets pulled along the surface may differ in contents if one of them is accidentally a little heavier than the other, or, for some reason, has been towed a little deeper.

The following figures from the German North Sea catches will illustrate the differences in the volume from different depths at the same stations:—

Depth at which catch was made.		c.cm. under 1 sq. metre area.		c.cm. in 1 cub. metre.
{ 35—5 metres	...	112	...	3·7
{ 5—0 „	...	56	...	11·3
{ 44—5 „	...	72	...	1·8
{ 5—0 „	...	72	...	14·4
{ 63—47 „	...	56	...	3·5
{ 47—5 „	...	144	...	3·4
{ 5—0 „	...	144	...	28·8

In the Baltic, volume estimations have been made and the catch also quantitatively examined. On one expedition, for example, the volumes from Stations 1, 2 and 3 in the West Baltic, where the salt contents was 17 to 20 ‰, were very large and above the average. At Station 8, a point further east, there was also a large catch, but the salt contents was only 8 to 10 ‰. The constitution of the catch varies in the Baltic, probably with the salt contents, which, unlike the North Sea, varies within wide limits. Thus, *Aphanizomenon flos-aquae* increases as one travels east. *Chaetoceros decipiens* and *C. didymum* decrease and eventually drop out altogether. *Ceratium* also decreases in the same way. At Station 8, however, where there was a low salt contents, this decrease for some reason was not present. In the North Sea the simple hydrographical conditions of the Baltic do not prevail, and the whole matter is rendered far more

difficult. The total volumes and the constitution of the catches made varies considerably at the different stations. Thus, in one of the expeditions at Station 9, North Sea, there was a greater quantity of *Ceratium macroceros* and an abnormal number of *Oithona* and *Pseudocalanus*. At Station 11 a great number of *Actinotrocha* larvae formed an important constituent in the catch. In May, 1903, there was in the North Sea a remarkable preponderance of plankton in the upper five-metre layer, far exceeding that of the deeper layers. This was quite independent of the salt contents, for it occurred where there was no difference in the constitution of the sea water between the surface and the bottom. Thus, at one Station the numbers for plant cells were in the proportion 0 to 5 metres deep, 400; 5 to 40 metres deep, 55; 40 to 75 metres deep, 8; 75 to 150 metres deep, 2; 150 to 450 metres deep, 1. In another example, however, there was a decrease as above from the surface down until the 25-metre depth was reached, but between 25 metres and 75 metres deep the average number of organisms present was twice as great as at the surface, that is, about twenty times what it should have been. This was due to an abundance of *Phaeocystis*. What determines these variations? Salt contents seem to have nothing to do with the diminution which occurs as one passes from the surface into deep water, though in the Baltic, as will be mentioned below, the salt contents seem to cause an opposite result. Light intensity might be connected with it, but very good catches are often obtained at depths of 75 to 100 metres. In the Baltic, in February, 1903, the figures gave different results for the vertical distribution, for the plankton was always more abundant in the deeper layers than at the surface.

The organisms which caused this increase were

*Ceratium balticum*, *C. longipes*, *C. macroceros*, *C. fusus*, Polychaete larvae, Copepod larvae, *Oithona similis*, *Centropages hamatus*, *Paracalanus* and *Pseudocalanus*. These are all forms which are characteristic of the North Sea and West Baltic water, where the salt contents are high. Owing to the peculiar conditions prevailing in the Baltic, a great variation occurs in the salt contents of the water, varying from 20 ‰ in the West to fresh water in the North-east, and, moreover, at any station there is commonly a great difference between the salt contents at the surface and at the bottom. It is, therefore, natural to presume here that the greater abundance of the plankton in the deeper layers was due to the salt contents of the water, since that was greater in these layers than at the surface, and the organisms present were those characteristic of salt water. At the present time, however, a great deal still requires to be learnt with regard to the relations between the plankton and the hydrographical conditions, and in many cases the results obtained so far contradict each other.

Finally, it is necessary to examine some of the extremely interesting statistics given by the Hensen method quoted by Jenkins and others. I refer first to such estimations as the number of Copepods in the West Baltic or the number of Peridinians annually devoured by a Copepod. We have only to consider how little we know of the conditions under which these plankton forms live, and the admitted inaccuracies of the method, to see that such results must be so hypothetical as to be of very little practical importance.

To one of the calculations I must refer in greater detail. The number of floating eggs of the cod and flat fishes found in the Eckenförde waters, the area of which is 16 miles, was estimated at 30 per square metre of the

surface for January, 45 to 50 for February, 60 for March, and 50 for April. The average depth of water is given as 20 metres, and the eggs take 15 days on the average, under the conditions prevailing in the Baltic, to develop, so that the above numbers must be doubled to give the number of eggs present per month under a square metre of surface water. This gives 370 eggs per square metre for the period January to April. From the returns of the Eckenförde fishermen, it was calculated that the cod and plaice annually caught would have produced 23,400 million cod and 73,895 million plaice eggs annually, if left in the sea.

These figures gave for every square metre of the 16 square miles over 26·6 cod and 84 plaice eggs, a total of 110·6 eggs, which represented the loss through the fish being caught. If this is added to the number 370 above calculated, the total 480·6 is the number of eggs produced by all the cod and plaice, captured and free, yearly for every square metre of surface water. The relation  $110\cdot6:480\cdot6=1:4\cdot4$ , and this is described as giving the ratio of the adult fish caught annually to the total number present in this area—a capture of a quarter of the total fish.

This argument is, however, incorrect for the following reasons. The number 110·6 represents the number of eggs under each square metre of the surface, assuming that all the eggs had survived which the fish caught annually were capable of producing in their ovaries. The numbers 23,400 million cod eggs and 73,895 million plaice eggs were arrived at from direct estimations of the number of eggs in the mature fishes. Now, it is well known that the cod and plaice produce a very large number of eggs, but that out of the enormous number only a certain proportion survive. Hence the need for such a



large number, and hence, also, the attempts made by fish hatcheries to save a greater number of the embryos by rearing them through the early stages.

Then, again, since unfertilised plaice and cod eggs do not remain pelagic and other dead eggs fall to the bottom (when their death is not due to their being devoured), the floating eggs capable of being caught must be but a small proportion of the number actually produced. Hence the number 110·6 is much too high, as a calculation of the number of eggs per square metre lost by the capture of the adult fish, and cannot be compared directly with the number 370, which although the actual number of eggs fished, represents only a portion of those produced. The calculation has assumed that the relation between the number of eggs floating in the sea and the fishes that produced them is the same as that between the number of eggs in the ovaries and a mature fish.

In conclusion, it may be repeated that for a scientific quantitative study of the plankton, the complete apparatus and the Hensen method of counting must be employed. It is quite obvious that a certain amount of inaccuracy will occur with the use of each piece of apparatus, and the numbers must be considered approximate only; but since the errors will average the same for each catch, they do not invalidate the results for purposes of comparison. It is quite another matter, on the other hand, if the plankton is found to be not so equally distributed that the small samples taken will give reliable results for the whole areas. It is not to be expected that under varying hydrographical conditions the plankton will remain the same; but, at the present time, very little is known of the actual relations. Again, it has been pointed out several times in this paper that the results of recent plankton work have very often shown sudden and striking

variations in the quantity and constitution of the catches at two stations where apparently the conditions prevailing were the same. Hensen and the later German workers regard these fluctuations that occur as of little importance; but it is clear that more knowledge upon this question of the unequal distribution is required, because if small samples (and they are only 15 c.cm. for the centrifuge) are to be taken, they will give no true picture of the plankton present in either quantity or quality, nor of the relations of larvae to adults, if swarms occur or if there is unequal distribution to any considerable extent. It is, therefore, very necessary to take a small region and to make sure that the hydrographical and other conditions are the same throughout, or to take catches in exactly the same way, side by side, or separated by the length of a vessel, in order, after a systematic research, to tabulate the fluctuations that have occurred. Herdman (**17**), who is working on these lines at Port Erin, has already given some surprising figures of the variations in the catch of two nets worked side by side, and the detailed account of his results, to be published in this volume (see **19**) should throw some light on this very important question.

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Fig.  
1.

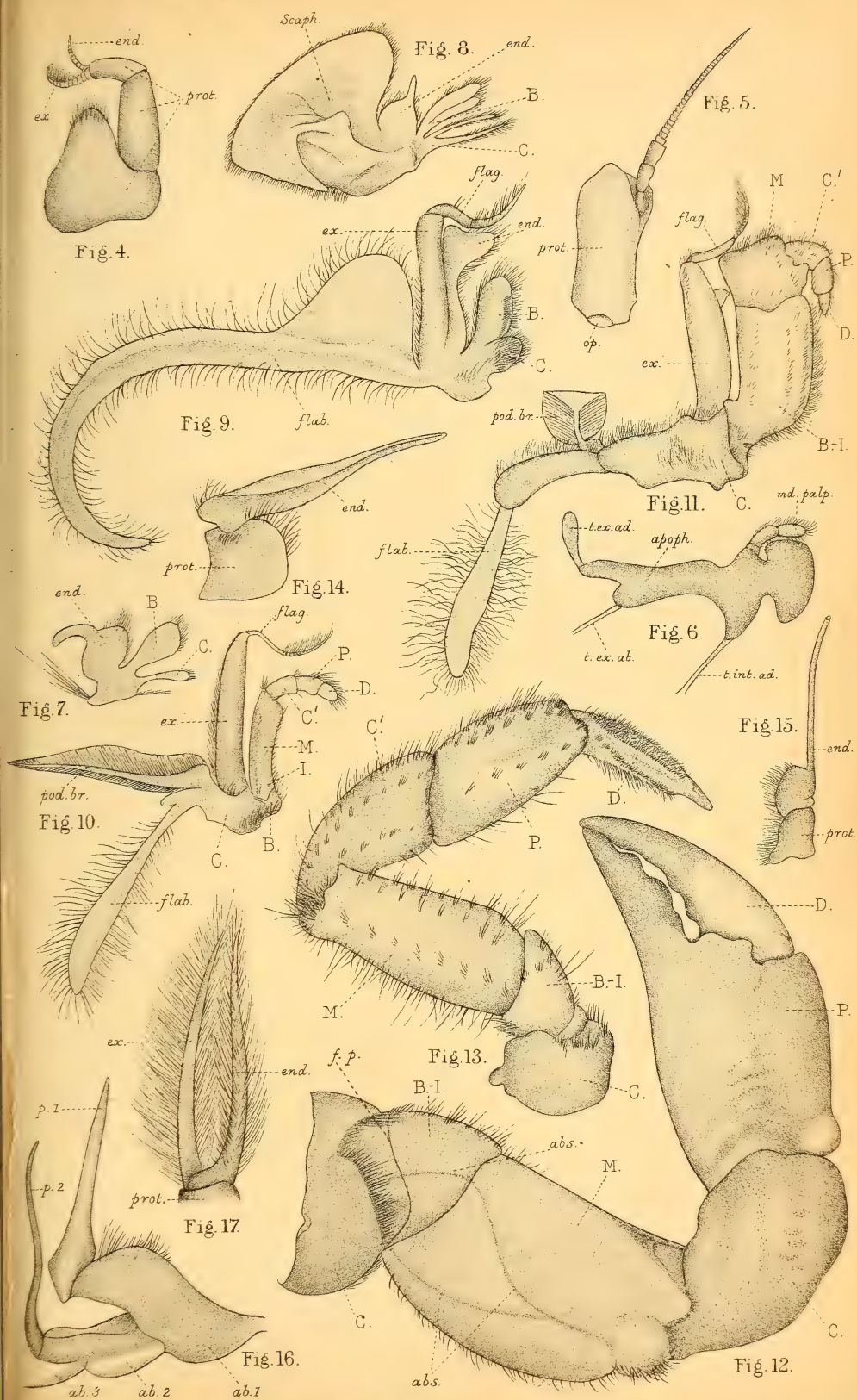


Fig.  
2.



Fig.  
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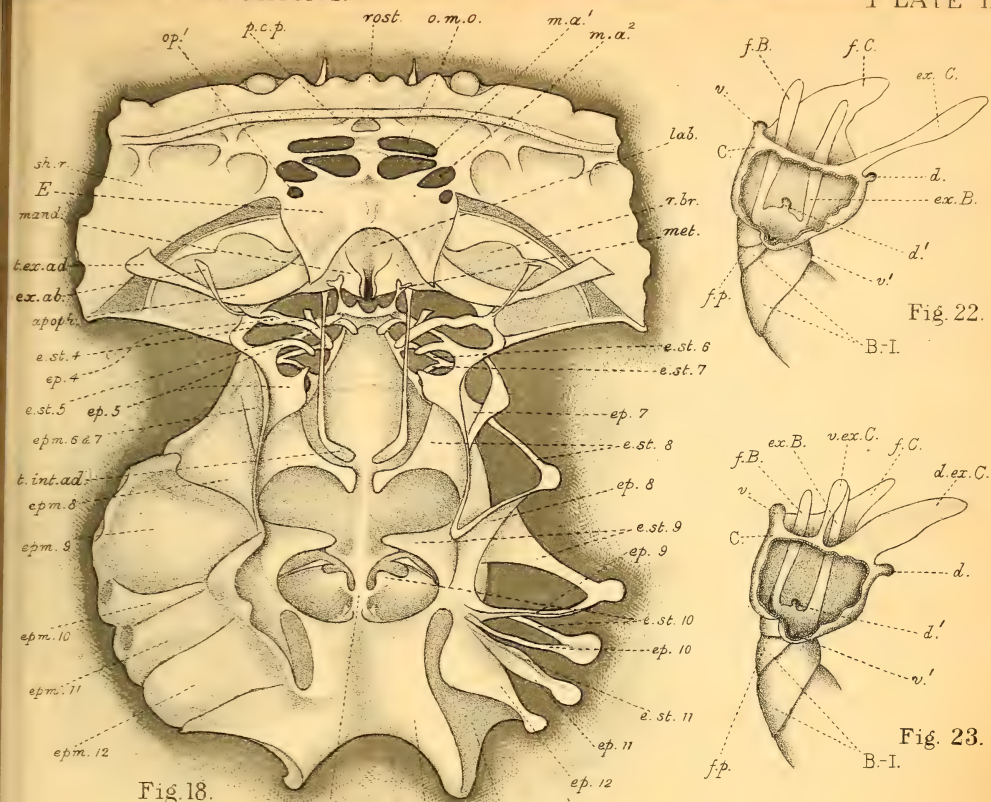


Fig. 18.

Fig. 22.

Fig. 23.

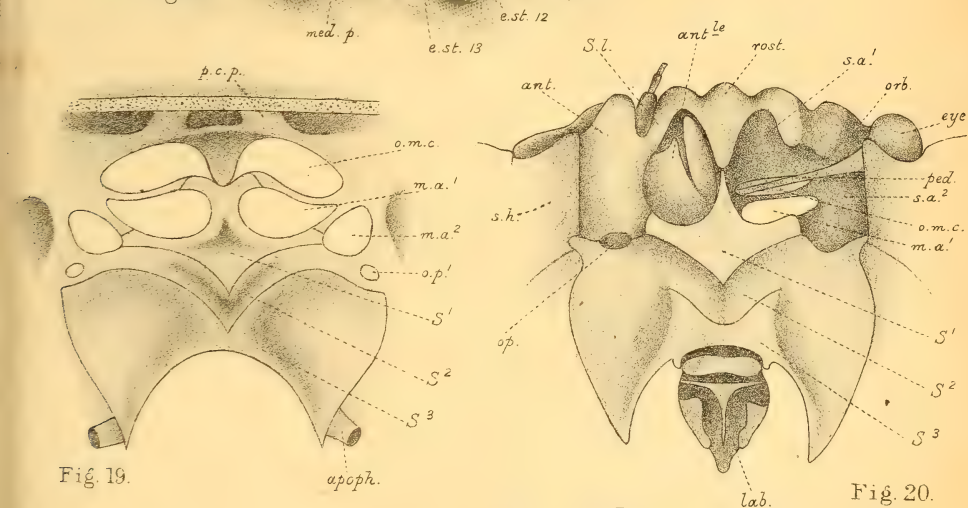


Fig. 19.

Fig. 20.

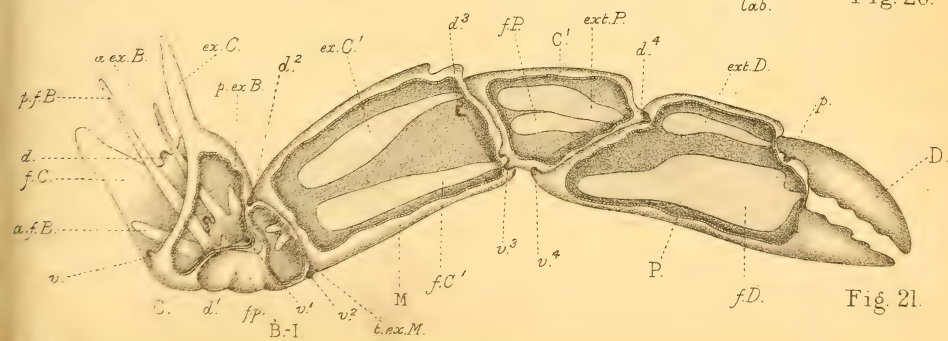


Fig. 21.



Fig 30.

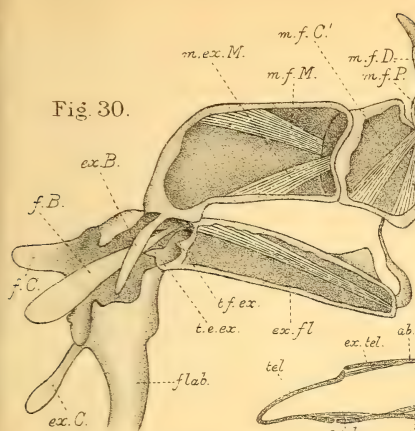


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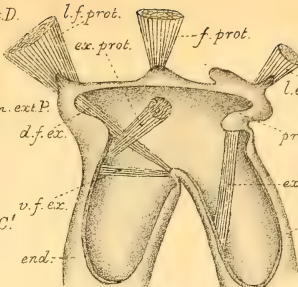


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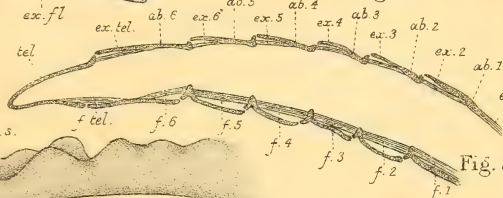


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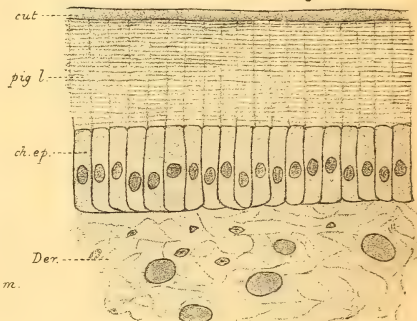
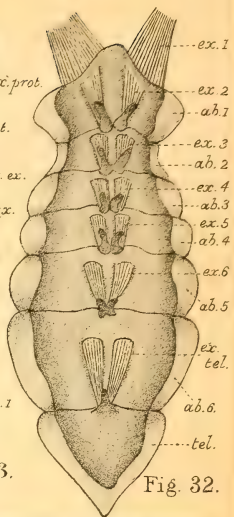


Fig 24.

Fig 31.

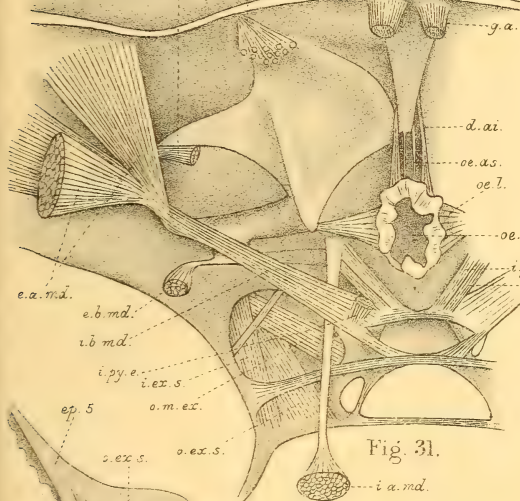


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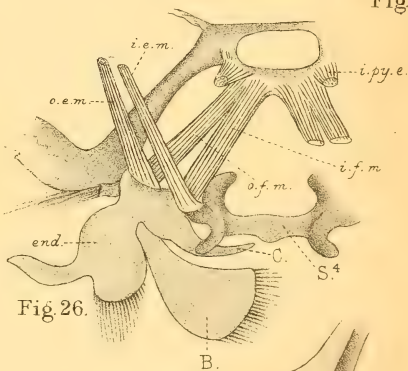


Fig 27.



Fig 28.

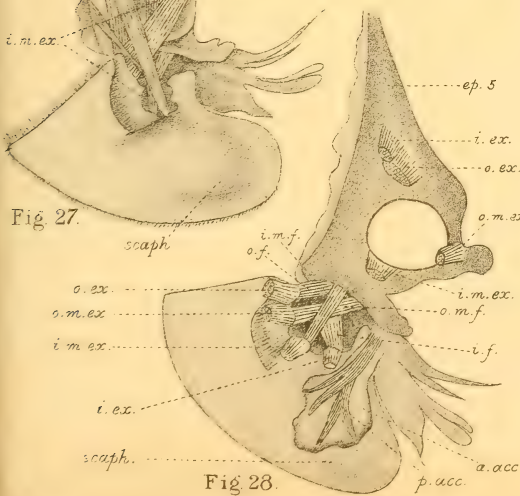
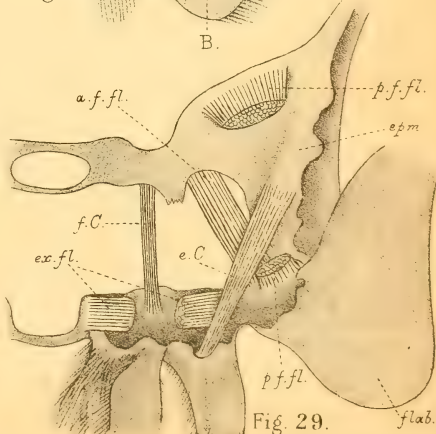


Fig 29.







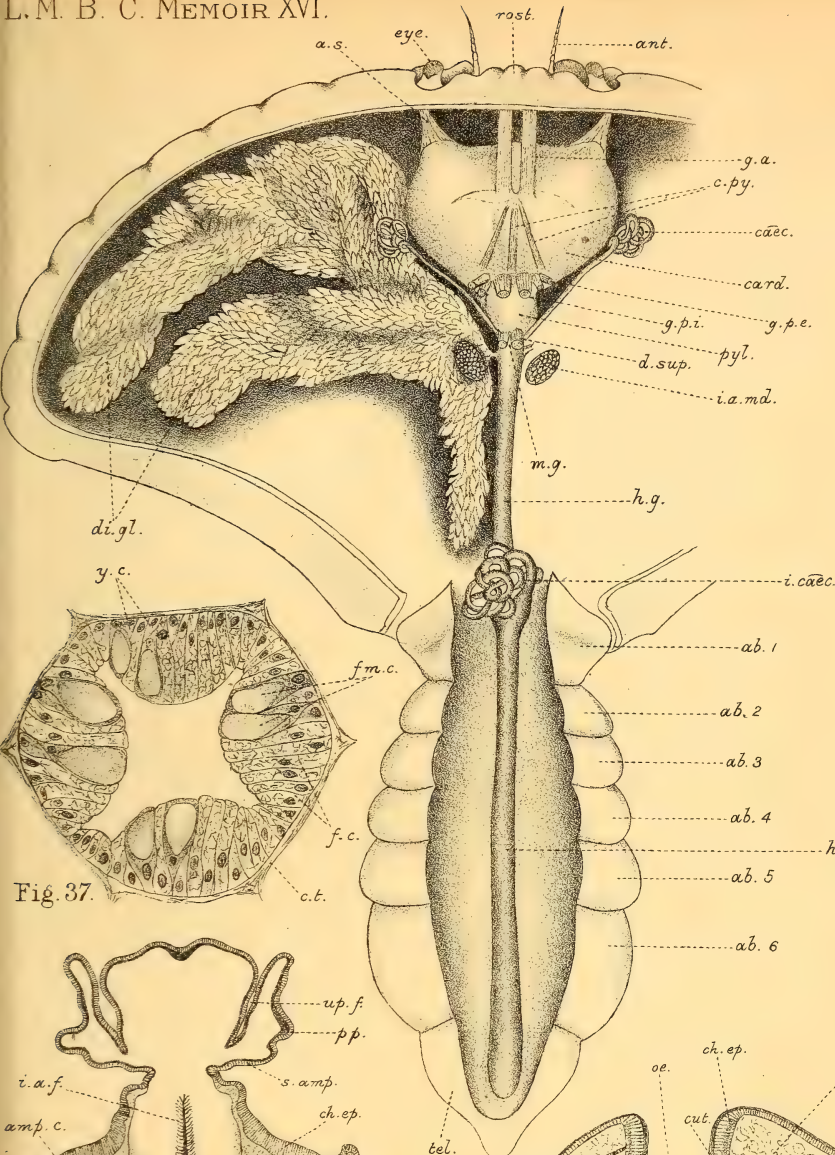


Fig. 34.

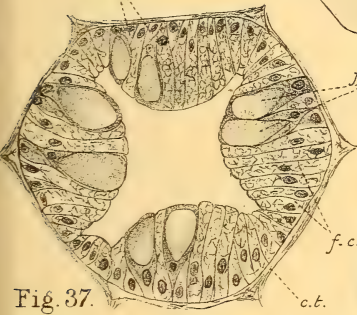


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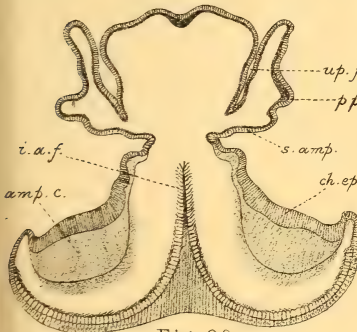


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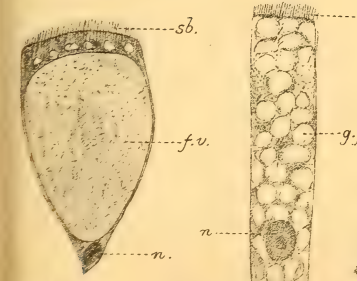


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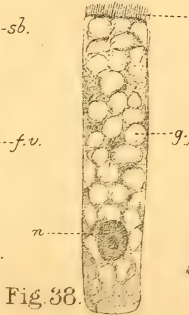


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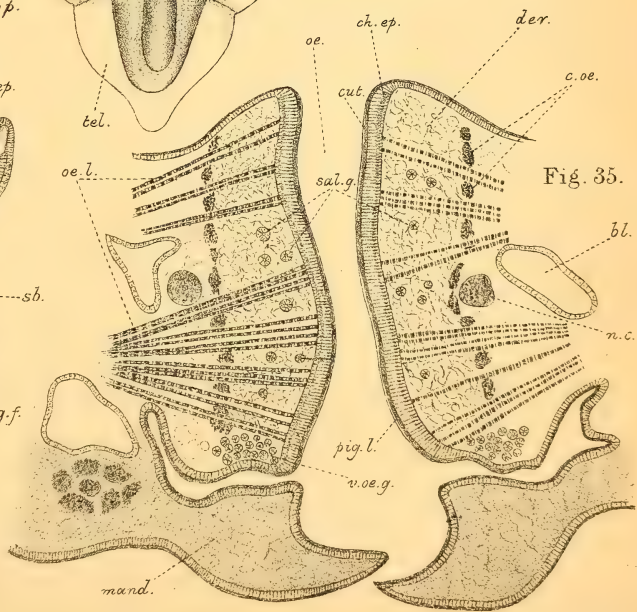


Fig. 35.



Fig. 43.

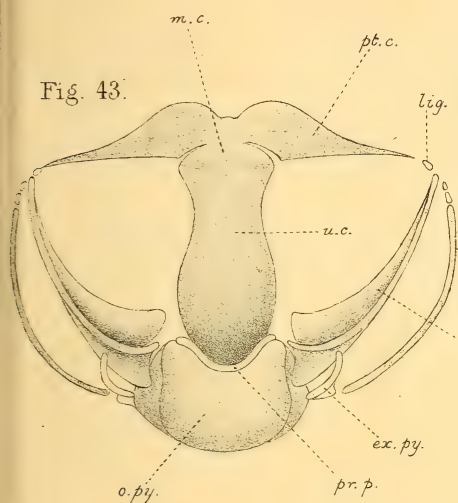


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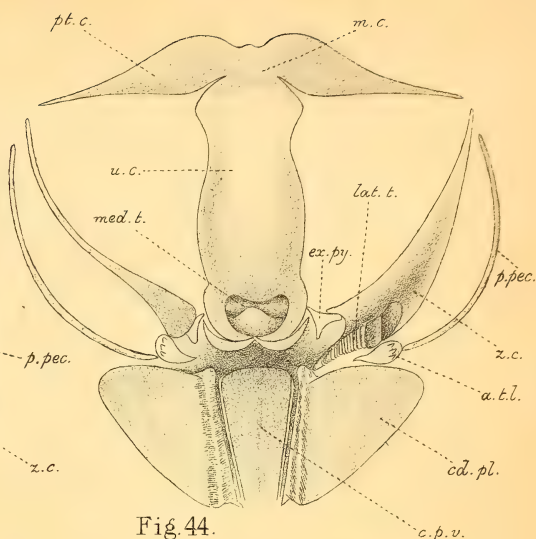


Fig. 41.

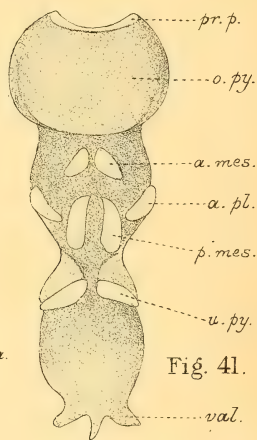
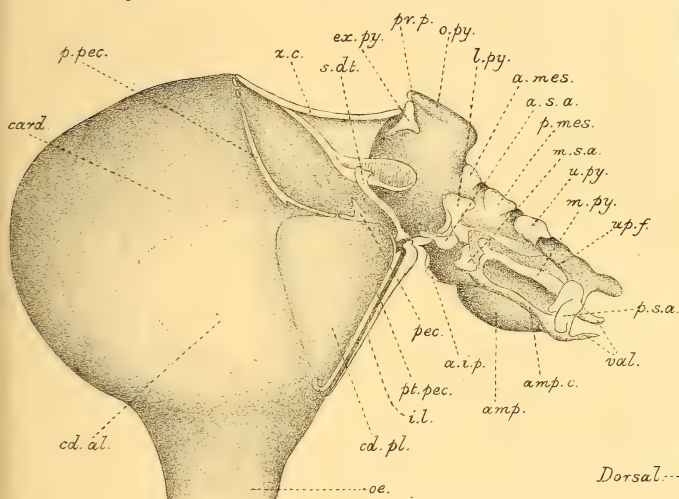


Fig. 40.



Dorsal

Fig. 41a.

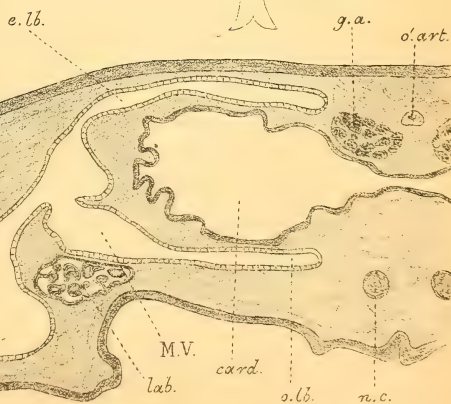
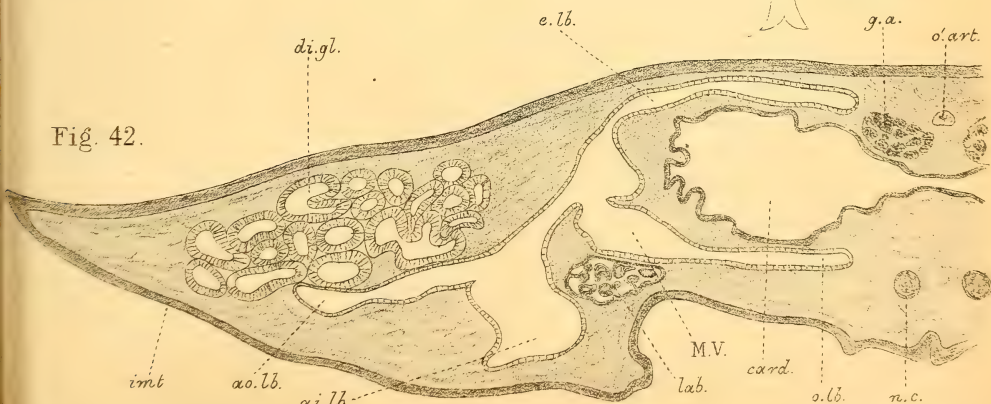


Fig. 42.







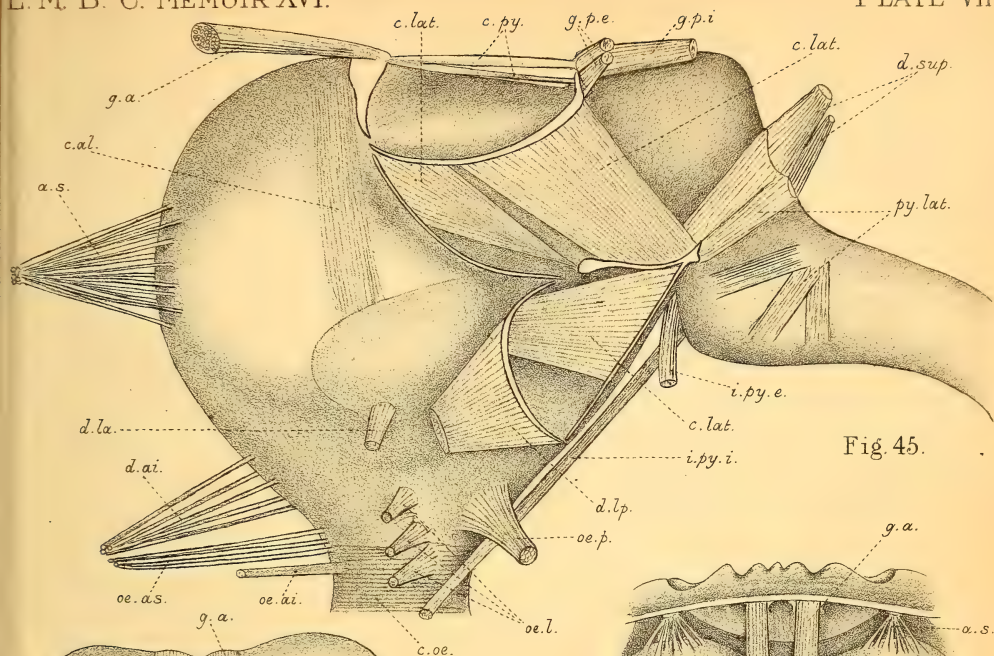


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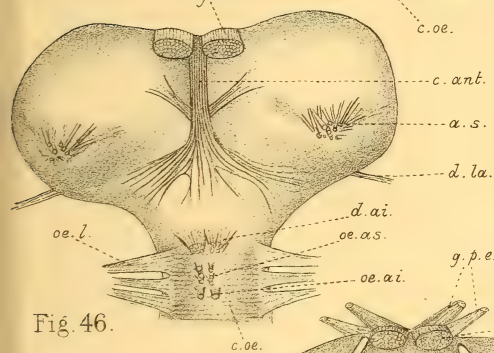


Fig. 46.

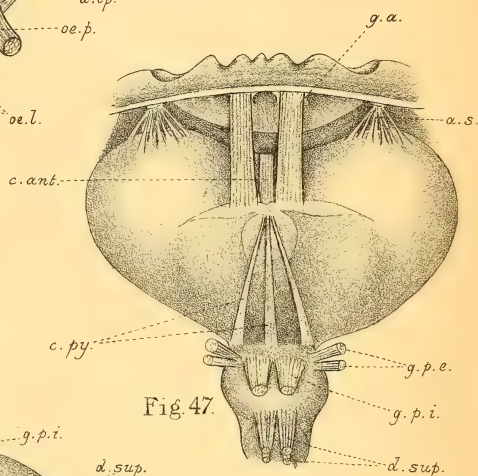


Fig. 47.

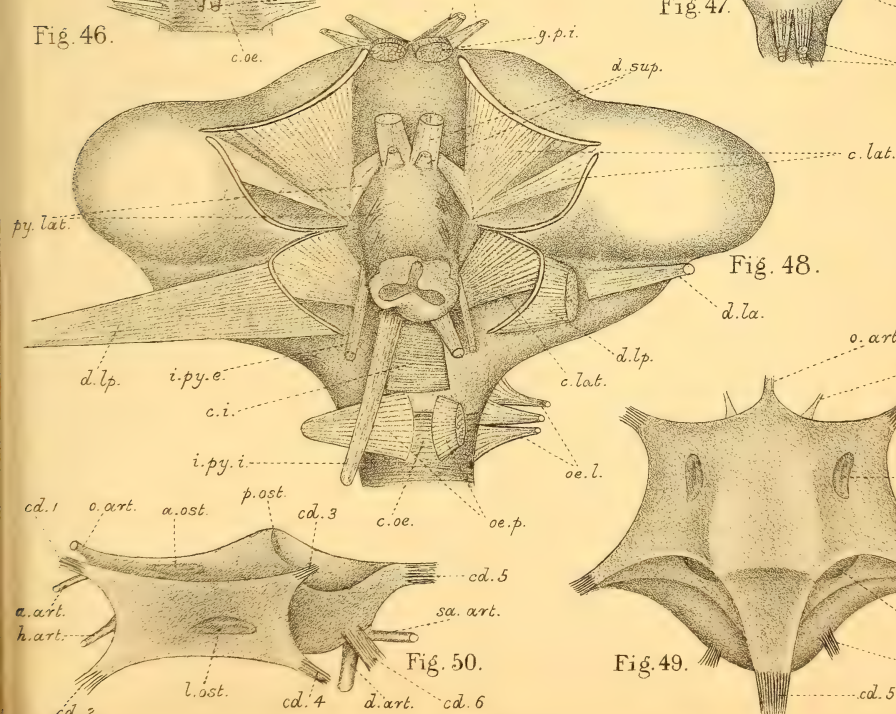


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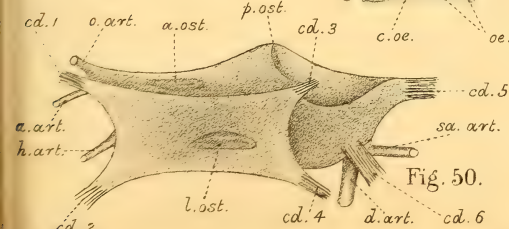


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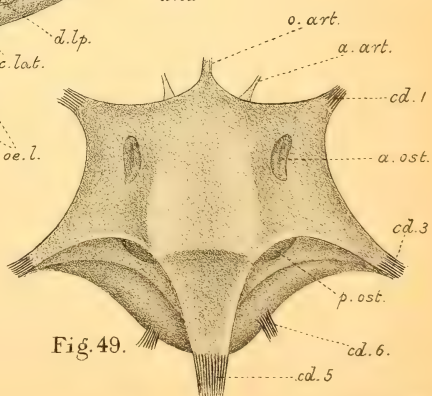


Fig. 49.





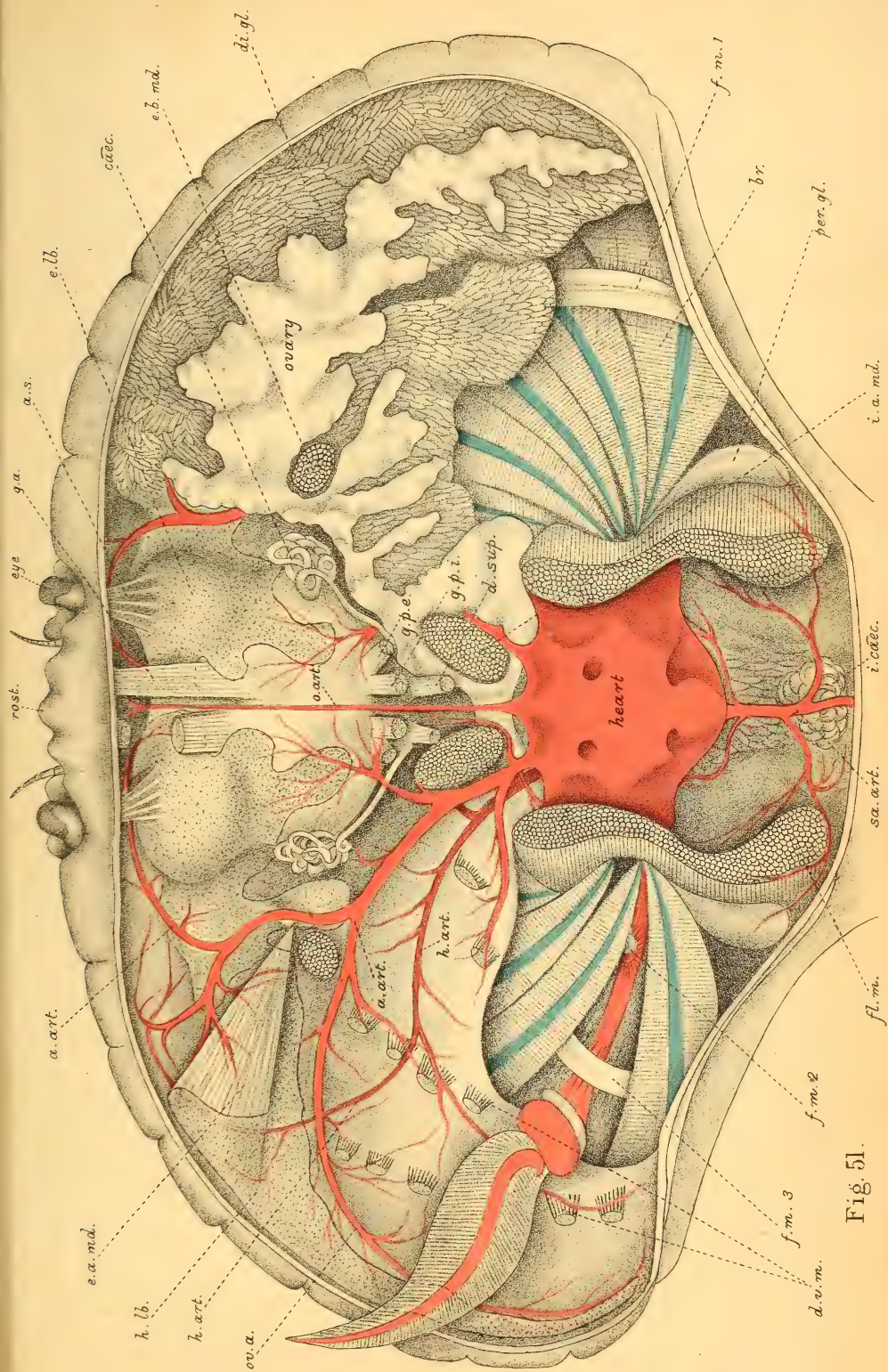


Fig. 51.





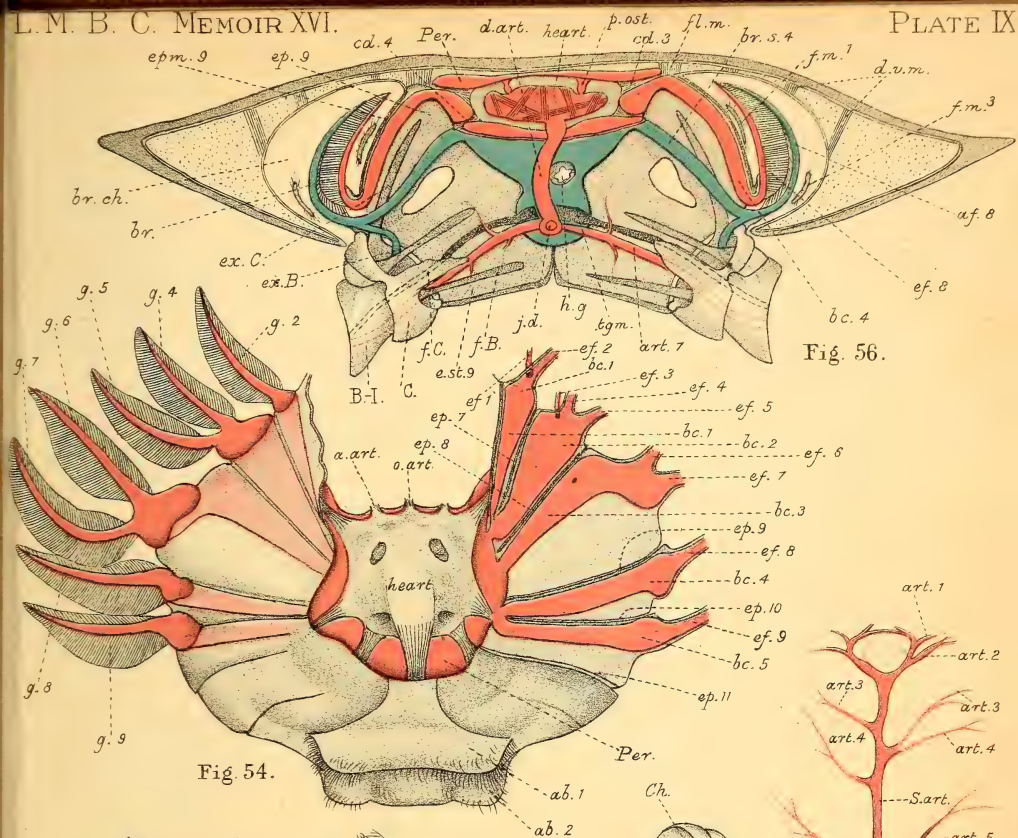


Fig 54.

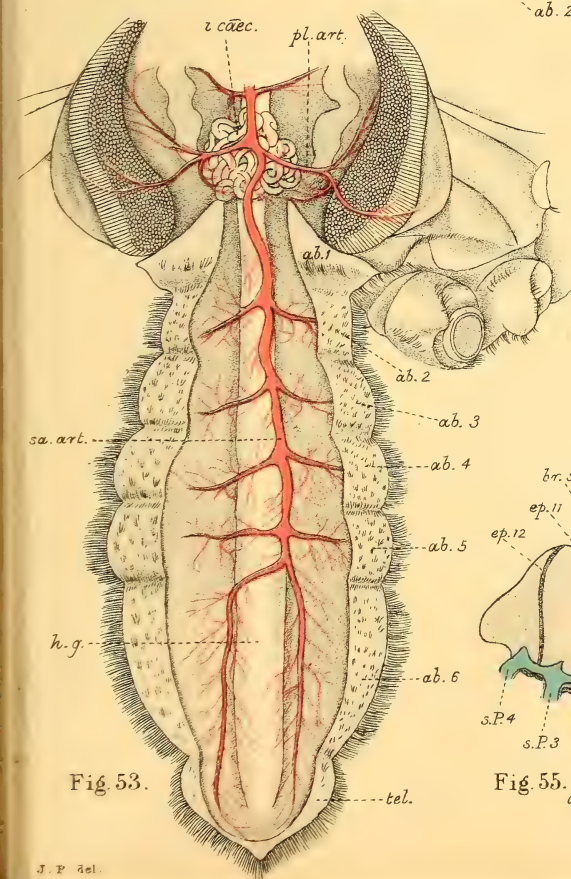


Fig 53.

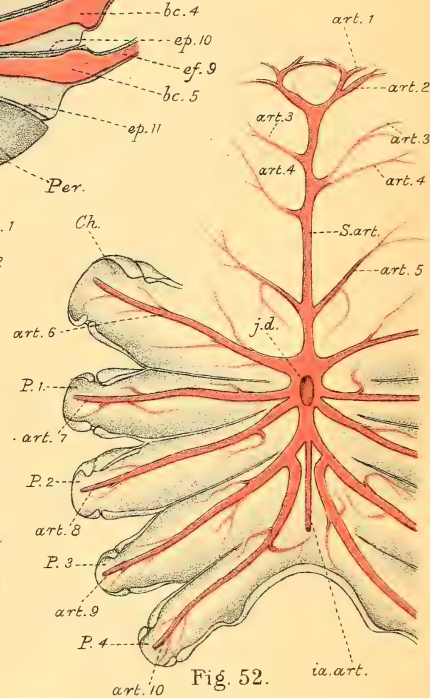


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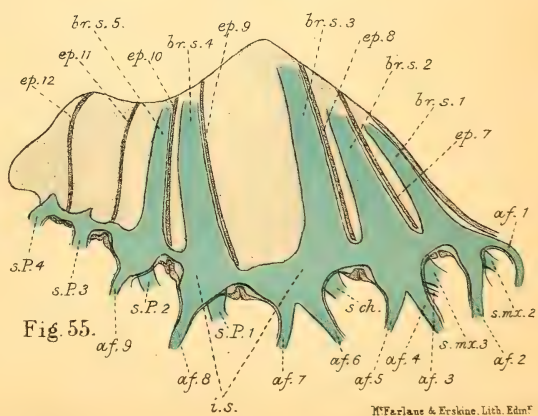


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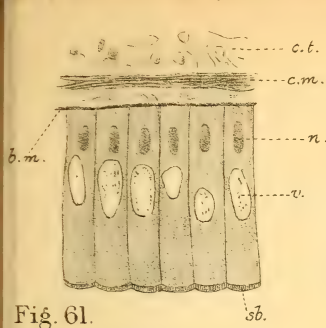


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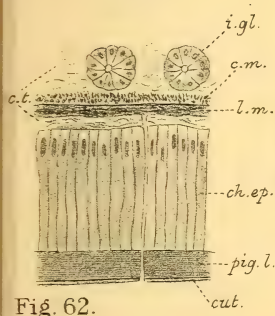


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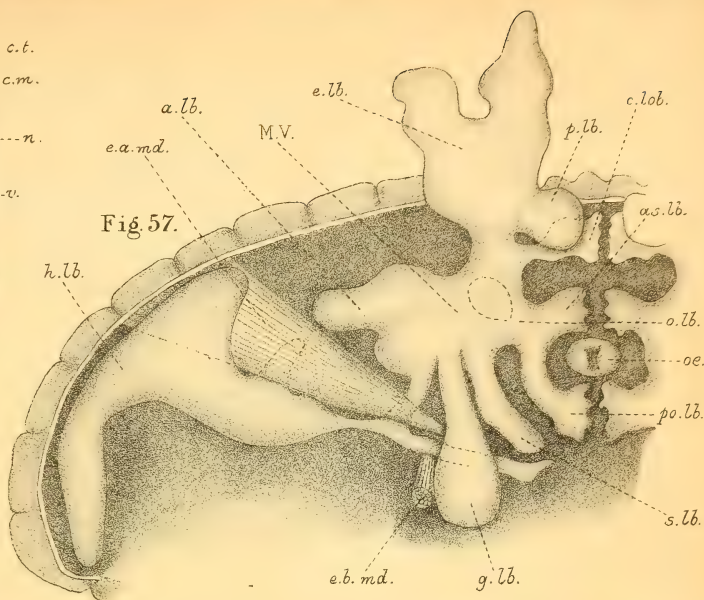


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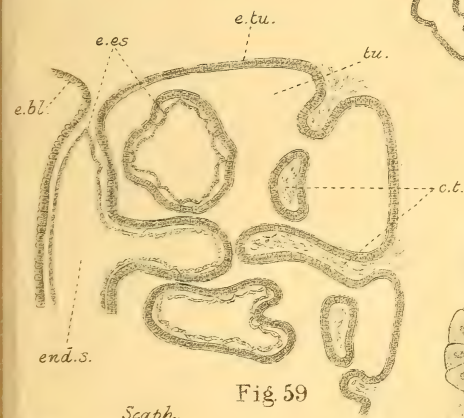


Fig. 59

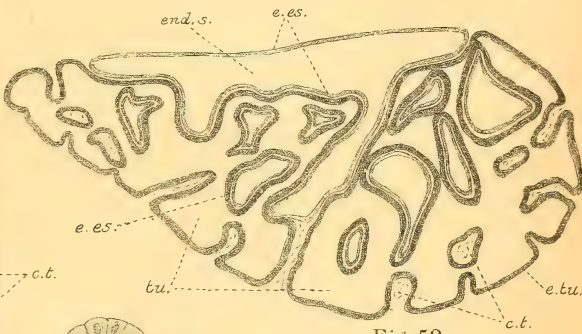


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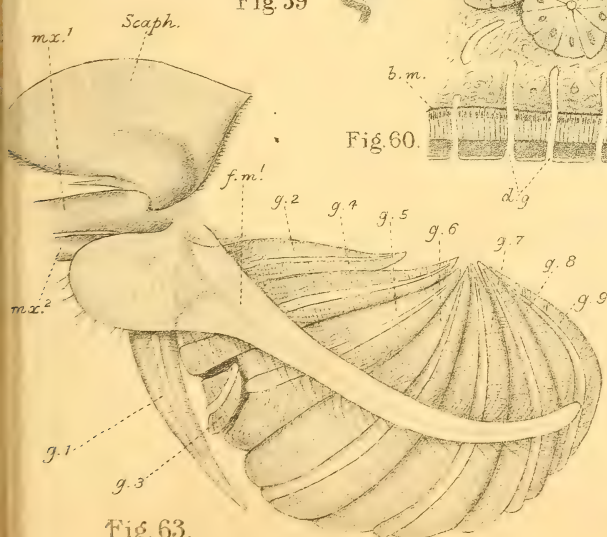


Fig. 63.

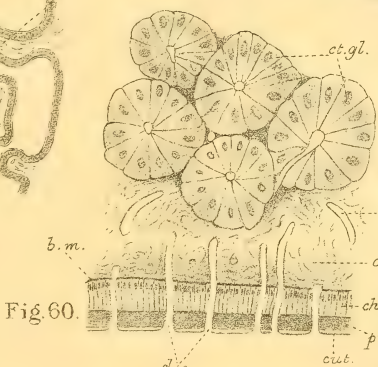


Fig. 60.

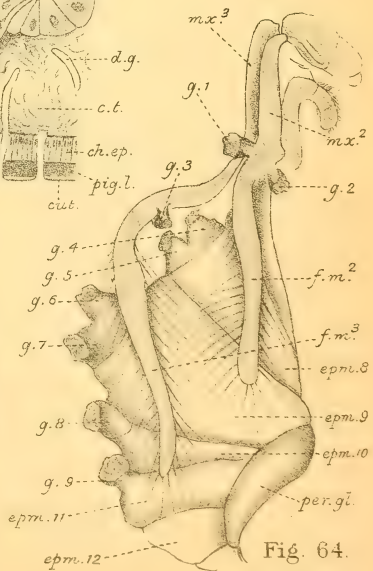


Fig. 64.







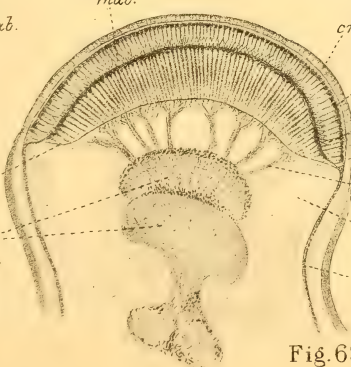
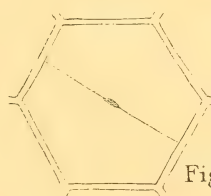
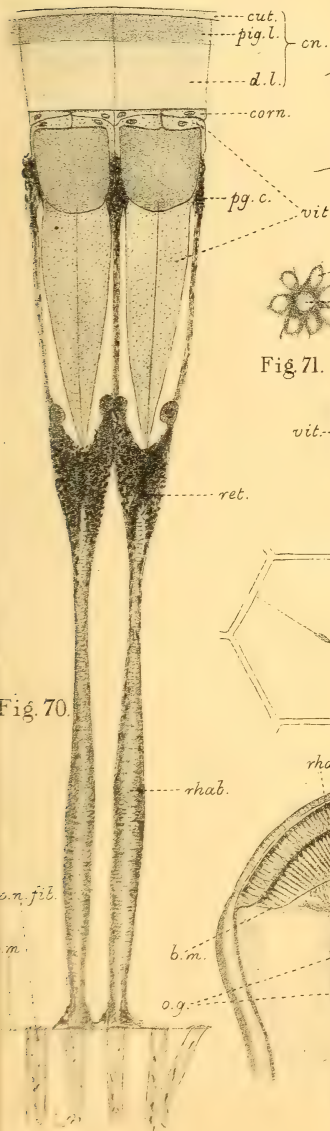
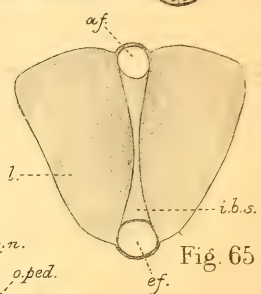
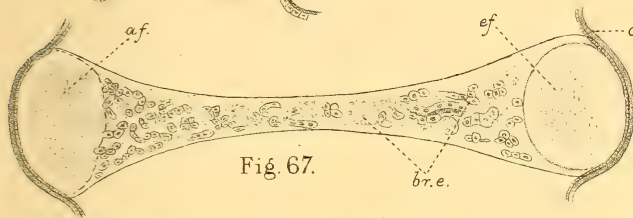
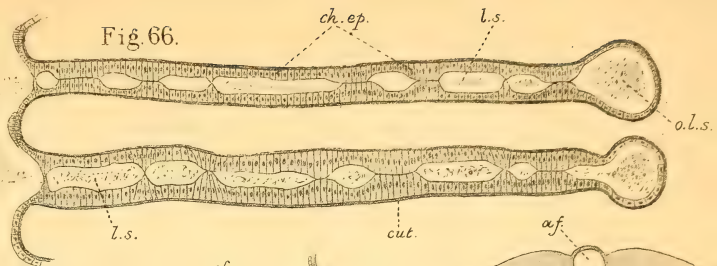


Fig. 68.

Fig. 69.



Fig. 74.



Fig. 75.

Fig. 76.



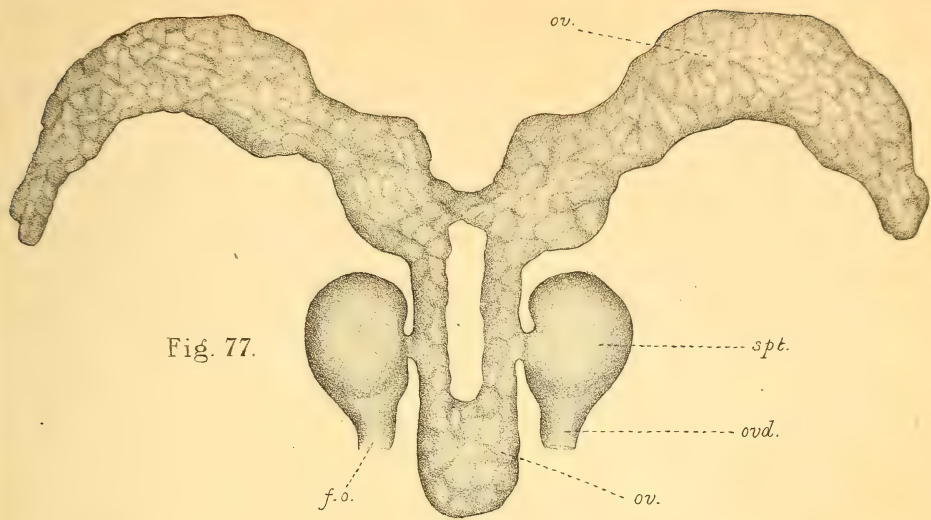


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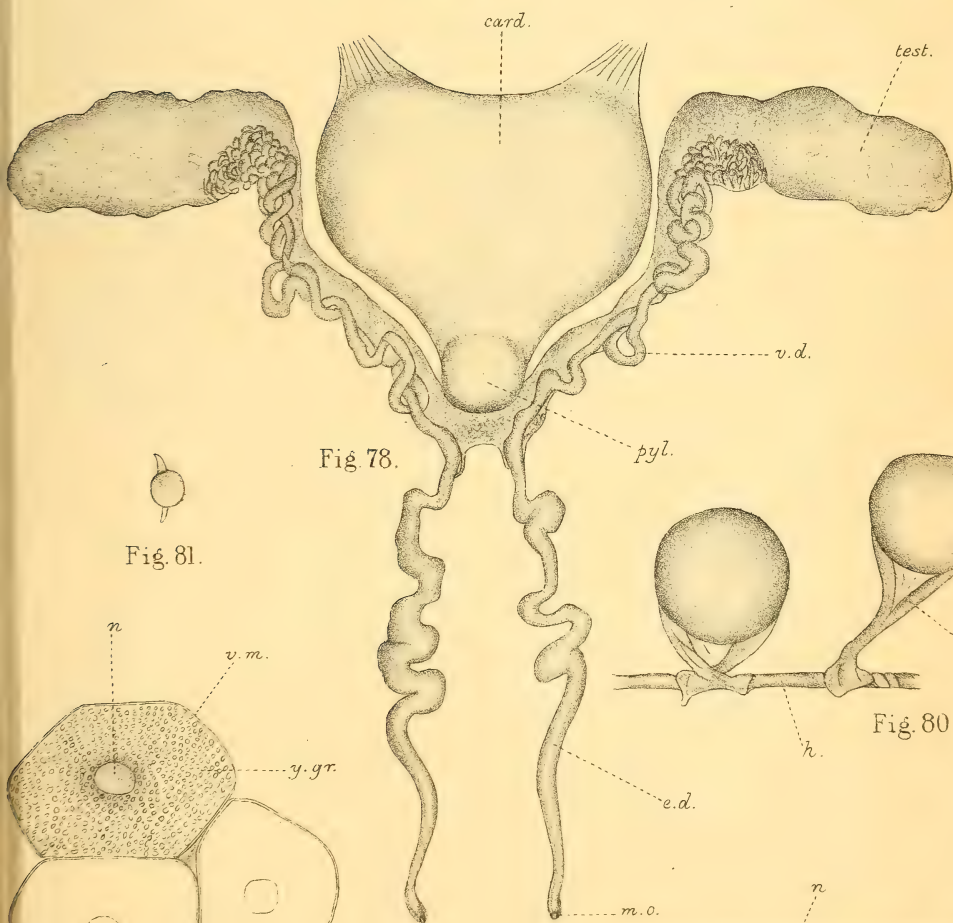


Fig. 78.

Fig. 81.

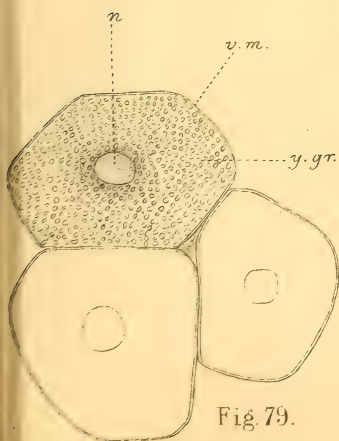


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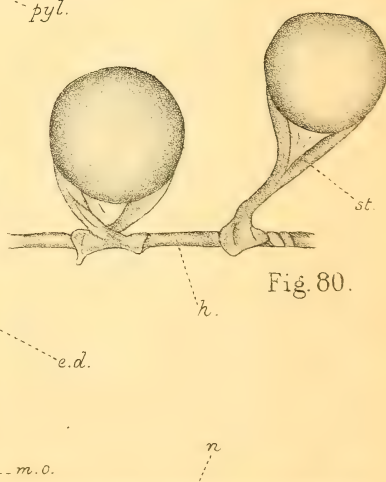
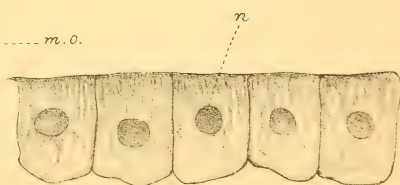


Fig. 80.

Fig. 82.







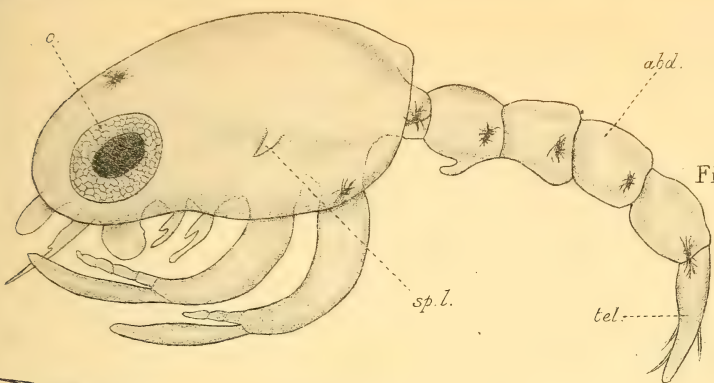


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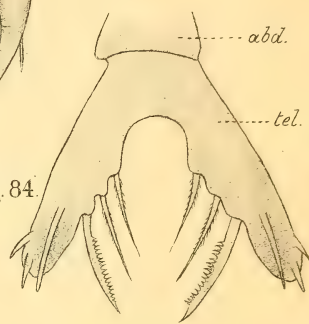


Fig. 84.

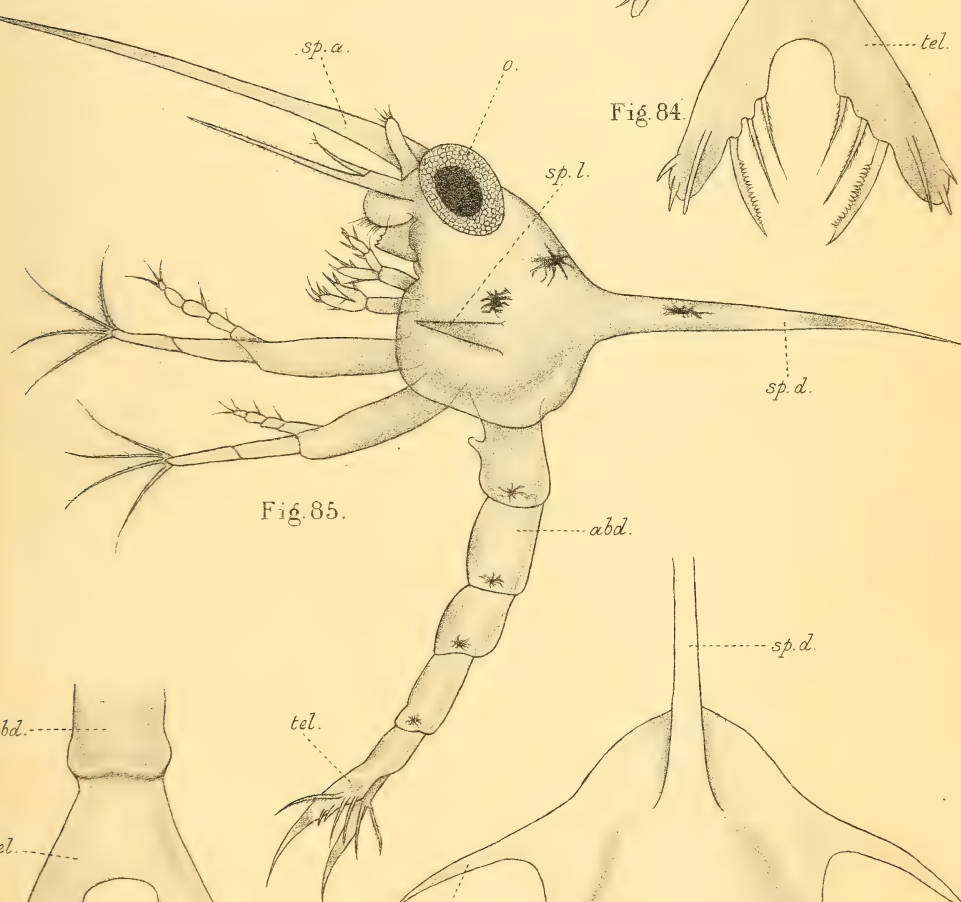


Fig. 85.

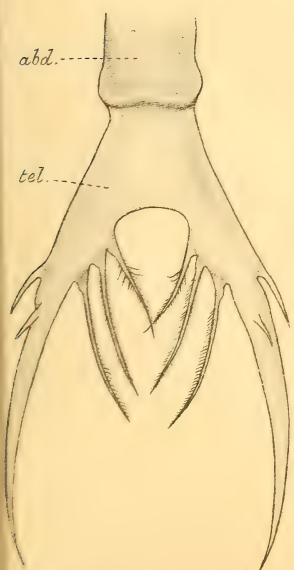


Fig. 87.

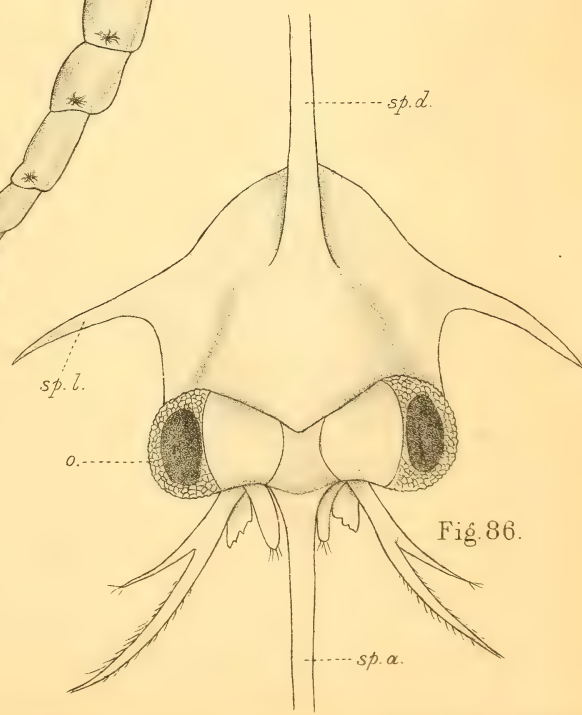


Fig. 86.



















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